THE

CYCLOPÆDIA

OF

ANATOMY AND PHYSIOLOGY.

VOL. IV.—PART I.

PLE—STA

1847–1849

THE

CYCLOPÆDIA

OF

ANATOMY AND PHYSIOLOGY.

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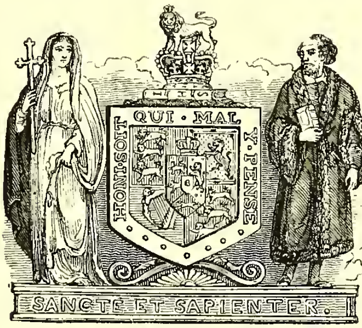

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LONDON

LONGMAN, BROWN, GREEN, LONGMANS, & ROBERTS.

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PLEURA is the name given to the serous sac of the lung and the cavity containing it. There are two pleural sacs, one for the right lung and right side of the thorax, the other for the left lung and left side of the thorax. These two sacs being apposed and adherent to one another in the middle line, form there a median, antero-posterior, vertical septum, called the mediastinum, which divides the thoracic cavity into two lateral compartments. Each pleura is, like all other serous membranes, with one exception, a shut sac; and there being but one organ contained in each pleural cavity, and that organ being of a tolerably simple form, the well-known comparison of a double nightcap, expressive of the manner in which a serous sac lines the interior of a cavity and invests the exterior of the viscus contained in it, is extremely apt in the case of these sacs lining the chest and covering the lungs. Of the two surfaces of the sacs, the inner one is everywhere free and the outer everywhere adherent; such in fact is universally the case with all serous membranes. Each pleura invests its respective lung, and lines the moiety of the thoracic cavity to which it belongs, in the simplest manner possible, as simply and accurately as though it were a coating of paint, dipping into the fissures of the lungs and into the acute angles formed by the costæ with the arching diaphragm in the most neat and accurate manner. It only remains then, in order to complete our description of the course of these membranes, to examine the manner in which they pass from the parietes to the viscus. It is thus:—the two pleuræ, above, below, behind, and in front, meet one another in or near the middle line, and form the mediastinum above-mentioned; between the layers of the mediastinum are situated the heart and great vessels and the termination of the trachea; from these issue on each side a bronchus, pulmonary artery, pulmonary veins, &c. destined to the lung, which, bound loosely together by areolar tissue, have received the appellation of the root of the lung; this root of the lung emerges from the mediastinum at about the middle of its posterior upper quarter, and is covered with a layer of the pleura, which thereby becomes conducted from this point of the mediastinum to the lung.

The term *mediastinum* is applied by some writers to the antero-posterior vertical septum of the chest, by others to the spaces occupied by the viscera situated between its layers; in the latter sense of the term three mediastina are enumerated —anterior, posterior, and middle; the anterior, which is very large, is the space occupied by the heart in its pericardium, thymus gland, or its remains, and phrenic nerves; the middle contains the bifurcation of the trachea, the arch of the aorta, the pulmonary and other great vessels; the posterior contains the aorta, œsophagus, &c. All these organs, their position, &c. will be found described in other parts of this work; their right and left aspects are invested by the right or left pleura respectively. It is in their larger interspaces only that the two pleuræ come into actual contact and adhesion with one another. The smaller interspaces are not intruded upon by the pleuræ, but are occupied with areolar tissue and fat. In most of the lower (mammalian) animals, where the chest is deep and narrow, and in the human fœtus, the two pleuræ come into adhesion with one ano-

ther in front of the heart; but in the adult human subject this is not the case, the pericardium coming into immediate contact with the anterior thoracic parietes. Also the pleuræ are prevented by the adhesion of the pericardium to the diaphragm from adhering to one another below the heart. It is almost superfluous to state that the heart and pericardium encroach more upon the left pleural cavity than upon the right. The median thoracic septum of the human subject is able, partly on account of its small antero-posterior extent, to resist any considerable lateral displacement, such as might result from accumulation of effusion into one pleural cavity; but in deep-chested animals it admits of displacement to such an extent that the whole of the chest may be filled with an effusion into one pleural cavity. In a Chetah, which died of pleurisy at the gardens of the Zoological Society, dissected by the author, the immediate cause of death was suffocation occasioned by effusion into the right pleura, which occupied the whole chest, and compressed the left lung, the left pleura being unaffected. The mediastinum may be regarded as a kind of mesentery to the heart, and in some reptiles it is very obviously seen to be a part of the great median mesentery wherein all the viscera are suspended. This great median mesentery of reptiles is attached to parietes in front as well as behind as far down as the falciform ligament of the liver; as though a fold of serous membrane had been pulled down by the umbilical vein. In some reptiles, as the chameleon, the anterior parietal attachment is continued even down to the small intestines, so that the stomach and part of the small intestine are enclosed between the layers of the mediastinum. The serial homology of this septum is obscured in Mammalia by the diaphragm being interposed between it and the other mesenteries.

The only fold or duplicature made by each pleura that is comparable to the mesenteries or omenta formed by the peritoneum is that called the broad ligament of the lung (*ligamentum latum pulmonis*). It is a fold carried downwards and backwards from the root of the lung. It may be described as having four edges, the upper one of which is attached along the lower aspect of the root of the lung; the outer one is attached to the inner aspect of the lung from its root to its lower border; the inner one is attached to the mediastinum from the root of the lung downwards and backwards to the œsophageal opening in the diaphragm; the remaining edge is free and directed outwards, downwards, and backwards. Its inner or mediastinal attachment is by far the longest, so that its figure is four-sided, with one corner extremely drawn out or prolonged.

There are frequently found, especially about the pericardium, numerous pyriform masses of fat covered with pleura, like appendices epiploicæ.

The outer surface of the pleura is but loosely adherent to the ribs and intercostal muscles; it is more firmly connected with the diaphragm and pericardium, and still more firmly with the lungs. The adhesion of the two pleuræ in the mediastinum is extremely loose in the human subject, large quantities of areolar tissue and frequently fat being interposed; so that in many subjects they can hardly be said to come into immediate contact at all.

The pleura covering the ribs and that forming the mediastinum is strengthened by a fibrous layer, but that covering the lungs is destitute of such fibres, and consequently extremely thin and delicate. The terms *pleura pulmonalis*, *pleura costalis*, and *pleura diaphragmatica*, are applied respectively to those parts of the pleuræ which are connected with the lungs, the ribs, and the diaphragm: and these expressions are frequently found extremely convenient.

From the extreme frequency of abnormal adhesions of the apposed surfaces of the pleura it appears that this serous membrane is unusually liable to inflammation, which liability may be due to its being unusually exposed to external circumstances through its extreme proximity to the air in the lungs.

The pleura is peculiar to the class Mammalia. In Birds the lungs are adherent to the thoracic parietes; and in Reptiles, there being no distinction of thorax and abdomen, they are invested by the peritoneum. To this, however, there is an exception in the Crocodilians, in which reptiles a rudimentary diaphragm exists. The pleuræ of these animals are disposed around the outer, anterior, and posterior, but not the inner aspect of each lung; so that the lung seems to be adherent to the mediastinum.

(Simon Rood Pittard.)

POLYGASTRIA.—A name applied by Professor Ehrenberg, of Berlin, to an immense class of microscopic animalcules which exist in countless millions in water of various kinds, both salt and fresh, more especially in such as contains decomposing animal or vegetable substances.

Many forms of these beings are indescribably minute, some of them measuring not more than the 32,000th part of an inch in length, and all of them are of such tiny dimensions as to require the utmost penetration of the microscope and the most patient industry on the part of the observer to make out their organization. A few of the largest are, indeed, barely distinguishable by the unassisted eye; but, generally speaking, they are quite invisible; and had it not been for the invention of the microscope, we should, even at this day, have been ignorant of their existence.

The numbers in which these creatures abound baffles all expression. It has been ascertained, and the fact may easily be proved with a good microscope, that, possessing the dimensions above referred to, say the 24,000th part of an inch, many of these living atoms crowd the water in which they are found to such an extent that they are not separated from each other by a space greater than the size of their whole bodies; so that by a very little calculation it will be seen that a single drop of such water contains more of these active existences than there are human beings upon the surface of this globe. And when the mind reflects upon their

universal distribution wherever water is to be met with fit for their reception, it is impossible not to be overwhelmed with the contemplation of a scene so calculated to impress upon us the infinitude of the works of the Creator.

Our knowledge of the class of animals under consideration dates from a very recent period. The earliest observers with the microscope, partly from the imperfection of their instruments, and partly from ignorance of any characteristic distinctions, were in the habit of grouping all the creatures of microscopic dimensions, which they perceived swimming in the water they examined, as belonging to the same category, under the name of "Infusorial Animalcules," a title which consequently embraced creatures of the most dissimilar forms and habits, and even widely removed from each other in the scale of animal existences by their internal organization and general economy; thus the Rotifera, the larvæ of insects, the gemmules of Polyps, and innumerable other minute creatures were confounded under the same denomination. It is to the researches of Ehrenberg, the great historiographer of these beings, that we are indebted for the breaking up of this chaotic assemblage, and the introduction of order where all was previously confusion and uncertainty.

Prior to his discoveries naturalists denied the existence of any alimentary apparatus in the Infusoria, believing them to be nourished by a kind of imbibition, and regarding the granular bodies contained within them as being their eggs or young ones. Ehrenberg, however, by placing indigo, carmine, sap-green, and similar extremely pure coloured vegetable substances in the water containing them, soon found that the coloured material was readily admitted into the interior of the body, and there disposed in such a manner as to convince him that there were numerous receptacles in the interior of these little beings, which he considered as forming their nutritive apparatus; and having applied to them the name of stomachs, he was induced to establish a distinct class for creatures thus organised, and distinguished them from all other animals by the name of POLYGASTRIA.*

These stomachs he subsequently discovered to be variously arranged in different genera, and was consequently induced to make these variations in the construction of the alimentary apparatus a basis on which to erect a scheme for their further subdivision. This kind of nutritive system of organs he found presented itself under different forms; in some species the stomachal cavities communicate separately with the oral orifice, so that there is no intestinal tube or passage of intercommunication between them: to such he has applied the term ANENTERA.† In all others there is a wide intestinal tube in the interior of the body, to the sides of which the numerous alimentary vesicles or reservoirs are appended, terminating by an anal orifice: these have been named from this circumstance ENTERODELA.*

The Enterodelous Polygastria are again divisible:—

1st. Into those in which the intestinal tube is disposed in a circular form in the interior of the body of the animalcule, winding round so that the mouth and anus are contiguous. (CYCLOCŒLA.†)

2nd. Into those in which the intestine traverses the body of the animalcule, passing along its longitudinal axis, and presenting two orifices completely distinct and opposite to each other; that which is anterior forming the mouth, the posterior the anus: such are characterized as ORTHOCŒLA.‡

3rd. Such as have a winding or twisted intestine, which never passes in a direct line through the long axis of the body: these genera are named CAMPYLOCŒLA.§

Such a classification, founded entirely on the anatomical arrangement of one set of organs, Ehrenberg acknowledges would be quite contrary to the established rules of zoology, were it not that the external characters of these animalcules are most exactly conformable with the structure of the alimentary canal; but finding that the Polygastria are thus resolvable into very natural families, he proceeds to classify them in the following manner:—||

Family 1.—MONADINIDÆ (*Monadidæ*). Polygastric animals, without intestinal canal, without external shell, body uniform, dividing by simple spontaneous fissure into two, but by cross divisions into four or several individuals.

- Monas.
- Uvella, (1, *fig.* 1.)
- Polytoma, (2, *fig.* 1.)
- Microglena, (3, *fig.* 1.)
- Phacelomonas.
- Glenomorum.
- Doxococcus.
- Chilomonas.
- Bodo, (4, *fig.* 1.)

Family 2.—CRYPTOMONADINIDÆ. Polygastric animals, presenting all the characters of the Monadinidæ, or at least deprived of the characteristic features of other families, and individually enveloped in a soft or slightly indurated shell.

- Cryptomonas.
- Ophidomonas.
- Porocentrum.
- Lagenella, (5, *fig.* 1.)
- Cryptoglena.
- Trachelomonas.

Family 3.—VOLVOCINIDÆ. Polygastric animals, without intestinal canal, without external

* πολὺς, *many*; γαστὴρ, *a stomach.*

† α, priv.; ἔντερον, *intestine.*

* ἔντερον, *intestine*; δῆλος, *manifest.*

† κύκλος, *a circle*; κοῖλος, *large intestine.*

‡ ὀρθός, *straight*; κοῖλος, *intestine.*

§ καμπύλος, *crooked*; κοῖλος, *intestine.*

|| In the following list it will be perceived we have omitted altogether the numerous families of Baccillariæ and kindred forms, being by no means satisfied as to their claims to rank as members of the animal creation. They stand, indeed, very dubiously between the domains of zoology and botany.

appendages, and with the body uniform, similar to the monads, but provided with an external envelope or shell, and dividing by complete spontaneous fissure beneath the common envelope into a number of animals which take the form of a polypary. At length the envelope becomes ruptured, and gives passage to the divided animals, which in their turn renew the same process of developement.

Gyges.
Pandorina.
Gonium, (7, 8, *fig.* 1.)
Syncrypta.
Synura.
Uroglena.
Eudorina, (9, 10, *fig.* 1.)
Chlamidomonas.
Sphærosira.
Volvox, (*fig.* 3.)

Family 4.—VIBRIONIDÆ. Animals either distinctly or most probably polygastric; filiform; without alimentary canal; without shell or external appendages; with the uniform body of Monads; associated in filiform chains in consequence of imperfect spontaneous (*transverse*) division.

Bacterium.
Vibrio, (1, 2, 3, 4, 5, *fig.* 5.)
Spirochæta.
Spirillum.
Spirodiscus.

Family 5.—CLOSTERINIDÆ. Animals distinctly or most probably polygastric, without alimentary canal, and without external appendages; body uniform, resembling the Cryptomonadinidæ in their envelope or shell, and dividing, together with their envelope, by spontaneous, transverse fissure, into a bacilliform or fusiform polypary; provided with moveable papillæ situated in the aperture of the shell.

Closterium, (6, 7, *fig.* 5.)

Family 6.—ASTASIEADÆ. Animals evidently or apparently polygastric, without alimentary canal, without external appendages or shell; changing their form to caudate or ecaudate at pleasure; body with a single aperture.

Astasia, (1, *fig.* 6.)
Amblyophis, (2, *fig.* 6.)
Euglena, (3, *fig.* 6.)
Chlorogonium, (4, *fig.* 6.)
Colacium, (5, *fig.* 6.)
Distigma.

Family 7.—DINOBRYINA. Animals distinctly or apparently polygastric; without intestinal canal; body with a single aperture; without external appendages; changing their form at will, and invested with a shell.

Epipyxis.

Family 8.—AMOEBAEADÆ (*Proteiform Animalcules*). Polygastric animalcules without alimentary canal; body with a single opening, furnished with variable processes, the shape of which changes at will; without a shell.

Amoeba, (7, 8, 9, 10, 11, 12, 13, *fig.* 6.)

Family 9.—ARCELLINIDÆ. (*Capsule Animalcules*). Animal polygastric, anenterous, loricated; body multiform, furnished with changeable foot-like appendages, covered with a univalve urceolate or scutellate shell, with a single aperture. = Amoeba enclosed in an urceolate or scutellate shell.

Difflugia, (1, *fig.* 7.)
Arcella, (2, *fig.* 7.)
Cyphidium, (3, *fig.* 7.)

Family 11.—CYCLIDINIDÆ (*Disk Animalcules*). Animals polygastric, anenterous, provided with appendages in the form of cilia or setæ; destitute of shell.

Cyclidium.
Pantotrichum.
Chaetomonas.

Family 12.—PERIDINAEADÆ (*Wreath Animalcules*). Animals visibly or probably polygastric, anenterous, loricated, vibrating; having setæ and cilia dispersed over the body or shell often in the form of a zone or crown; shell with a single opening.

Chætotyphla.
Chætoglena.
Peridinium.
Glenodinium.

Family 13.—VORTICELLINIDÆ (*Bell Animalcule*). Animals polygastric, having a distinct intestinal tube, with two openings, the oral and anal apertures being distinct, but situated in a depression common to both; without shell; either solitary and free, or fixed and frequently associated, developing themselves by imperfect spontaneous division, and frequently assuming the form of beautiful little bunches.

Stentor, (*fig.* 8.)
Trichodina.
Urocentrum.
Vorticella, (*fig.* 9.)
Carchesium.
Epistylis.
Opercularia.
Zoothamnium.

Family 14.—OPHRYDINIDÆ (*Loricated Bell Animalcules*). Polygastric animalcules, having a distinct intestinal tube, the apertures of the mouth and anus being distinct, although situated in the same fossa; loricated; solitary or aggregated. (= *Vorticellina loricata.*)

Ophrydium, (*fig.* 10.)
Tintinnus.
Vaginicola, (9, *fig.* 11.)
Cothurnia.

Family 15.—ENCHELIADÆ (*Rolling Animalcules*). Animals polygastric; having a distinct intestinal canal, the apertures of the mouth and anus being situated at the opposite extremities of the longitudinal axis of the body; without a shell.

Enchelis, (1, 2, 3, 4, 5, *fig.* 11.)
Disoma, (6, 7, *fig.* 11.)
Actinophrys.
Trichodiscus.
Podophrya.
Trichoda.
Lachrymaria, (8, *fig.* 11.)
Leucophrys, (1, *fig.* 12.)
Holophrya.
Prorodon (2, *fig.* 12.)

Family 16.—COLEPINIDÆ (*Box Animalcules*). Polygastric animalcules, having a distinct intestinal canal, the mouth and anus

being situated at the opposite extremities of the body; loricated. = Encheliadæ furnished with a shell.

Coleps, (1, 2, *fig.* 13.)

Family 17. — TRACHELINIDÆ (*Neck Animalcules*). Animals polygastric, furnished with a distinct intestinal canal, having an oral and an anal opening, but of these the anal opening only is terminal; without shell.

Trachelius, (3, 4, 5, *fig.* 13.)
Loxodes.
Bursaria.
Spirostoma.
Phialina.
Glaucoma.
Chilodon.
Nassula, (1, *fig.* 16.)

Family 18. — OPHRYOCERCINIDÆ (*Swan Animalcules*). Animals polygastric; having a distinct intestinal tube, furnished with two openings, that of the mouth only being terminal; without a shell.

Trachelocerca, (3, 4, *fig.* 16.)

Family 19. — ASPIDISCINIDÆ (*Shield Animalcules*). Polygastric, loricated, animalcules; having an intestinal canal furnished with two orifices, of which one only, viz. the anus, is terminal.

Aspidisca.

Family 20. — COLPODEADÆ (*Breast Animalcules*). Animals polygastric; without a shell; intestinal canal distinct, with two openings, neither of which is terminal.

Colpoda, (2, 3, *fig.* 18.)
Paramecium, (1, 4, *fig.* 18.)
Amphileptus, (2, *fig.* 16.)
Uroleptus.
Ophryoglena.

Family 21. — OXYTRICHINIDÆ (*Hackle Animalcules.*) Animals polygastric; without shell; having an intestinal canal with two distinct orifices, neither of which is terminal; provided with vibrating cilia, and also with styles or uncini, which are not vibratile.

Oxytricha.
Ceratidium.
Kerona.
Urostyla.
Stylonychia.

Family 22. — EUPLOTIDÆ. (*Boat Animalcules.*) Animals polygastric, loricated; with a distinct alimentary canal having two orifices, neither being terminal. = Aspidisca with neither orifice terminal, or Oxytricha provided with a shell.

Discocephalus.
Chlamidodon.
Himantophorus.
Euplotes, (*fig.* 19.)

All the above families are grouped by Ehrenberg under the following orders and sections, which, as it will facilitate the observations of the microscopist, as well as be a convenient guide to us in studying the economy of these little beings, we will subjoin in a tabular form, premising that the illustrious naturalist of Berlin found it advisable to separate the Polygastria into two parallel series, one comprising all such as were destitute of a shell (NUDA), the other embracing those which are furnished with such a covering (LORICATA).

ANENTERA.

This includes all animalcules which possess neither an internal nutritive tube nor an anal orifice, the mouth being in communication with several nutritive vesicles. These may be divided into the following sections:—

1*st Section.* GYMNICA.

Animalcules whose body has no external cilia nor pseudopediform prolongations.

Nuda.	*Loricata.*
Monadina.	Cryptomonadina.
Vibrio.	Closterina.

2*d Section.* EPITRICHA.

Exterior of the body ciliated or furnished with setæ and without pseudopediform prolongations.

Nuda.	*Loricata.*
Cyclidina.	Peridinæa.

3*d Section.* PSEUDOPODIA.

Body provided with variable pseudopediform prolongations.

Nuda.	*Loricata.*
Amoeba.	Bacillaria.

SECOND DIVISION.—ENTERODELA.

This division includes all animalcules having an internal digestive canal provided with a mouth and anal opening.

4*th Section.* ANOPISTHIA.

Mouth and anus contiguous.

Nuda.	*Loricata.*
Vorticellina.	Ophridina.

5*th Section.* ENANTIOTRETA.

Mouth and anus terminal and opposite; reproduction by transverse division.

Nuda.	*Loricata.*
Enchelia.	Colepina.

6*th Section.* ALLOTRETA.

Mouth and anus terminal and opposite, as in the last section; reproduction by longitudinal and transverse division.

Nuda.	*Loricata.*
Trachelina.	Aspidiscina.

7*th Section.* KATOTRETA.

Mouth and anus not terminal; reproduction as in last section.

Nuda.	*Loricata.*
Kolpodea.	Euplota.
Oxytrichina.	

Taking the above classification for our guidance, we must now proceed to investigate more minutely the organization of the strange animals included in this extensive series.

Locomotion.—Although no special locomotive apparatus has as yet been discovered in the family of Monads, this perhaps depends rather upon our deficient means of investigation than upon their absence. Attentive observation shews that every true Monad is furnished with a minute filiform proboscis, (1, 2, 3, *fig.* 1,) which, as it constantly exhibits an undulatory or vibratory motion, has been mistaken by some observers for a ciliary apparatus. Sometimes two of these organs are present, but this cannot be regarded as an essential characteristic feature, seeing that during the process of spontaneous fissure an animalcule which previously had only one proboscis, becomes

furnished with two preparatory to its separation into two individuals. In some species, however, two are constantly present. These proboscides may possibly discharge a double function, and perform the duty both of locomotive and of prehensile organs with which to collect nourishment.

In the Cryptomonadinidæ likewise one or two filiform proboscides, similar to the above, seem to be the locomotive organs; and the vibratile apparatus that serves for the movements of the Volvoces is entirely composed of similar structures belonging to the individual animalcules that constitute the compound bodies of these wonderful beings.

Amongst the Vibrionidæ the locomotion is of a very different character. In the true Vibrios it is performed by a kind of meandering or undulating movement, the fibre-like compound body of the animal bending and straightening itself alternately, the cause of which seems to depend upon a stronger binding together and subsequent relaxation of the individual animalcules, so that these seem to displace one another. In Bacterium the contraction is weaker, so that no undulating movement is produced, although the creature swims straight forward.

In the family Closterina (6, 7, *fig.* 5) the locomotive organs consist of numerous short, soft, conical papillæ, situated near the openings of the shell at the two opposite extremities of the animal; they are placed upon the inner side, and can be protruded but a very little way from the shell.

In the family Amoeba no special locomotive organs are met with. The round, gelatinous, and highly contractile bodies of these creatures have the capability of thrusting out at will foot-like processes from any part of their body, by the assistance of which they manage to move about. A similar mode of progression is met with in the Arcellinidæ. In all the higher forms of Polygastric Infusoria locomotion is effected by means of *cilia* variously distributed over different parts of the body, but their position in different genera will be described when speaking of the external forms of the different families.

These *cilia* are described by Ehrenberg to be minute hairs arising from a thick bulbous basis, upon which they execute a rotatory motion, some of them being continuous with their basis, while others are only articulated thereunto; of these the former kind exists in *Stylonychia mytilus*, and the latter in *Paramecium aurelia*.

In addition to the cilia some forms of animalcules (*Oxytrichina*) possess *setæ*, which are likewise stiff moveable hairs, but which are without any power of vibration; these organs are used in standing and climbing. Sometimes they are without any thickened basis, as in *Actinophrys;* generally they are pointed, but occasionally have a knob at the end.

A fourth set of locomotive organs are the *styli*. These are thick straight setæ, which in some forms of animalcules are attached like the tail feathers of a bird to the hinder part of the body of the animalcule: such styli do not vibrate like cilia, neither are they implanted in a bulb-like basis, nor bend like hooks, but serve merely as instruments of support, or are useful in climbing the stems of aquatic plants.

Lastly, many races are furnished with *uncini* or hooklets; these are merely bent, hook-like *setæ*, which, being thick and strong, and situated upon the ventral surface of the animalcule, seem to take the place of feet: they do not vibrate, but are implanted into a bulb-like root, which permits them to be moved in all directions; and although they are not articulated, they resemble very much the limbs of articulated animals.

So various, however, are the forms of the different families of Polygastric animalcules, that the above general view of their locomotive organs gives but a very imperfect idea of this part of their economy; and it will, therefore, be necessary, before we proceed further, to describe more at length some of the most interesting genera belonging to the class, for so strange and remarkable is the organisation of some of them that no generalisation would answer our present purpose. Some are single and isolated individuals, moving freely wherever they list; others are strangely compounded of aggregations of numerous animalcules associated into one common body, all of which must cooperate in rowing about the microcosm which they collectively form; some are affixed to highly irritable stems, whereby they are attached to various foreign bodies; some are naked, others covered with shells: in short, nothing but a rapid glance at the whole group will enable us satisfactorily to discuss the many curious circumstances discovered in connection with their history.

The family Monadinidæ embraces numerous animalcules, which, however different in external appearance, are evidently related to each other in all essential parts of their structure.

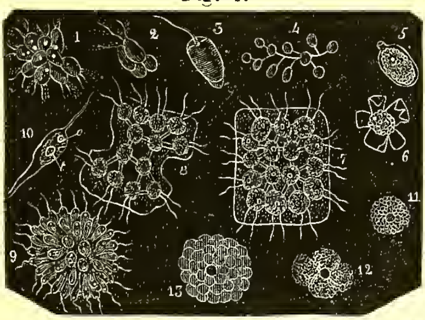
The Monads, properly so called, are so small that the utmost penetration of the miscroscope is insufficient to display their outward form with any degree of distinctness, much less to reveal their internal structure, some of them being not larger than from the 1,000th to the 3,000th of a line, or the 36,000th part of an inch in diameter. Under the highest powers of the microscope they have the appearance of almost invisible globular active specks, swimming about with the greatest facility, and never impinging against each other during the rapid dance that they continually execute. Their numbers are absolutely beyond human appreciation, as may be readily understood from the following computation of the multitudes sometimes met with.

The *Monas crepusculum*, found in infusions of putrid flesh, crowds the drop of water in which it is found to such an extent that there seems to be no interspace whatever between the individual animalcules. Supposing these animalcules to be, as is generally the case, $\frac{1}{2000}$th of a line in diameter, their number will then amount, in a drop of water of the size of

a single cubic line, to *eight thousand millions*, and a cubic inch of such water containing 1728 cubic lines, will be peopled with thirteen billions eight hundred and twenty-four millions of these living and active beings!!!

It has been possible to detect, even in these smallest of nature's works, an apparatus that seems to perform the functions of an instrument of progression. This consists in one or sometimes two filaments of extreme tenuity, which resemble somewhat the tail of a tadpole; here, however, the organ performs the functions of a proboscis, being appended to that part of the body which advances first in swimming. The shape of the Monads is not always globose, but sometimes egg-shaped, pear-shaped, elongated, or fusiform. In Monas tingens we have

Fig. 1.



1. *Uvella glaucoma*. 2. *Polytoma uvella*. 3. *Microglena monadina*. 4. *Bodo socialis*. 5. *Lagenella euchlora*. 6. The same crushed, showing its shell. 7. *Gonium pectorale*. 8. *Gonium pectorale*, breaking up into its component animalcules. 9. *Eudorina*. 10. One of the animalcules comprising *Eudorina* detached. 11, 12, 13. Developement of *Volvox*.

an example of the last form, and also of the manner in which they are sometimes found associated by their tails into beautiful groups, their double proboscides being all protruded externally.

This faculty of clustering together is still better exemplified in the genus *Uvella*, (1, *fig.* 1,) which somewhat resembles a transparent mulberry rolling itself about at will, whence the name " grape monad," which these animalcules bear. In *Polytoma* (2, *fig.* 1) this clustered appearance is due to the fact that the original animalcule is continually dividing into a greater and still greater number, which, at last breaking loose from each other, become solitary and independent.

Some animalcules of this family, as *Chilomonas destruens*, live in the interior of dead Rotifers and other minute beings, in which locality they seem to revel luxuriously; whilst others, as *Bodo*, (4, *fig.* 1,) are met with in the intestinal canal of many living animals,* from the fly and the earth-worm up to fishes and even men. One species *(B. ranarum)* seems particularly partial to the intestines of Frogs, in the contents of which it is usually found. Many species of this genus are furnished with long tails, by the aid of which they are bound together in bunches of very beautiful appearance, as represented in the figure.

In the Cryptomonads, (5, *fig.* 1,) which seem to be merely Monads invested with a shell, the proboscis is of a similar character; but these animalcules are never found associated in bunches.

Perhaps few more beautiful objects exist in nature than the next group of animalcules belonging to the Monadine type. These are the Volvocinidæ, embracing several genera composed of numerous Monads, associated together and connected by a common envelope, which constitutes a kind of compound polypary or monadary, as it has been recently called, through which the proboscides of the component Monads are exserted.

In *Gonium*, (7, 8, *fig.* 1,) one of the simplest forms belonging to this family, the common body resembles a minute square-shaped flattened tablet, so transparent as to be detected with great difficulty, in which the green Monads are set like the gems in the breastplate of the Jewish high-priest, from which circumstance one species, *G. pectorale*, has been named.

The organisation of *Gonium pectorale*, as far as it has been made out, seems to be as follows:—The mantle or proper covering of each individual animalcule, which can only be properly examined after the division of the little tablet, is neither four-cornered nor table-like, but pretty nearly round, and in the form of a *lacerna*, which the animalcules can quit and renew again at intervals. The table-like investment of the compound body is produced by regularly repeated spontaneous fissure in the longitudinal, but not in the transverse direction, which is in fact only an imperfect division into single tablets. In a little tablet of this kind all the animalcules of which it is composed appear to be connected to each other by riband-like prolongations.

It is only in *Gonium pectorale* that locomotive organs have been satisfactorily detected, presenting themselves under the usual form of two thread-like proboscides, appended to the mouth of each individual Monad entering into its composition. These are seen to be in constant motion, so as to have the appearance of cilia.

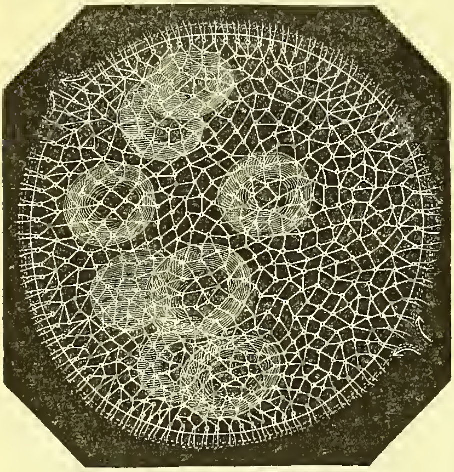
Each individual animalcule inclosed in the common envelope of the compound being appears, moreover, to possess a distinct nutritive apparatus, consisting of transparent vesicles visible among the green matter that fills its interior; but these have not yet been observed to fill themselves with colouring matter. Ehrenberg likewise supposes that each of the component animalcules of the Gonium contains the essential parts of a double sexual system, regarding the green-coloured particles in the body as eggs, and an opaque spot and contractile bladder, which is occasionally discernible, as the male apparatus; but these parts will be more particularly described hereafter.

The most beautiful animalcules belonging to the Volvocinidæ are the *Volvoces*, from which

* Ehrenberg, Infusionsthierchen.

the family derives its name. These, which may readily be procured in summer time, are sufficiently large to be visible to the naked eye, and when examined with a microscope, even of very humble power, present a spectacle of indescribable beauty; turning continually upon their axes, and revolving majestically through the drop of water that forms their space, they have the appearance of so many microscopic worlds (*fig*. 2). The parietes of these elegant spheres are thin and pellucent as the walls of an air-bubble; and in their interior, which is obviously fluid, may at times be seen rotating on their axes a second generation moving freely in the interior of their parent, and only awaiting the

Fig. 2.



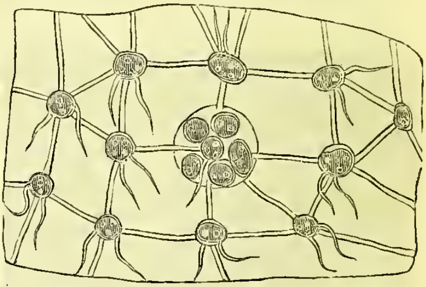
Volvox Globator, much magnified.

destruction of the original Volvox to escape from their imprisonment.

It was Ehrenberg* who first made the discovery that these beautiful living globes were not, as had until then been universally believed, single animalcules producing gemmules in the interior of their transparent bodies, which on arriving at maturity by their escape through the lacerated integument of the parent terminated its existence, but that they formed in reality the residences of numerous individuals living together in a wonderful community. This great observer had long remarked that the Volvoces appeared to take no food, neither were any of those vesicles discernible in their interior which in all other races of Infusoria he regards as the organs of nutrition—a circumstance which, considering their very great size when compared with other races, was well calculated to arrest attention; and he soon found that the structure of their nutritive appatus lies much deeper and is of a far more delicate character than any one could have previously anticipated.

On attentively examining with glasses of high power (1000 diameters) the minute green specks which stud the transparent covering of the Volvox, and which he had previously regarded as the bulbous roots of locomotive cilia, he perceived in each corpuscle a bright red point, and moreover discerned that instead of its being a cilium which was appended thereto, it was a whip-like moveable proboscis exactly similar to that of the Monads described above; and further observation convinced him that every green point was in reality a distinctly organised Monad, possessing mouth, eye, stomachs, generative apparatus, and, in fact, all the viscera attributed by Ehrenberg to the free Monadinidæ, and that the Volvox was entirely made up of an association of similar individuals (*fig*. 3).

Fig. 3.

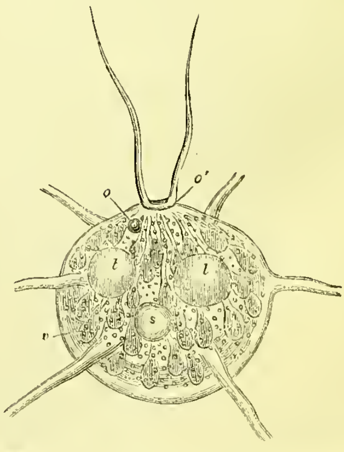


A portion of Volvox Globator still further magnified.

He further observed that in young specimens the component animalcules were perpetually undergoing spontaneous fissure, the result of which was the regular production of two, four, eight, sixteen, thirty-two, &c. distinct animalcules from one individual, until the resulting globe, *i. e.* the Volvox, was completely arrived at its natural dimensions.

The Volvox Globator may therefore be regarded as a hollow tegumentary vesicle, the origin of which is due to the incomplete spontaneous fissure of innumerable Monads, each of which is not more than 1.500‴ in diameter, but all completely organised.

Fig. 4.



An individual monadine of Volvox Globator magnified 1000 diameters.

* Abhandlungen der Koniglichen Academie der Wissenschaften zu Berlin, Jahr 1833, p. 328.

On closer inspection it is seen that all the Monads, which are placed at regular distances, communicate with each other by delicate threads, which form a kind of reticulation in the common gelatinous skin-like integument of the compound body, or polypary, as it might be aptly called, out of which the contained animalcules only protrude their proboscides either in search of food or to row the general mass along.

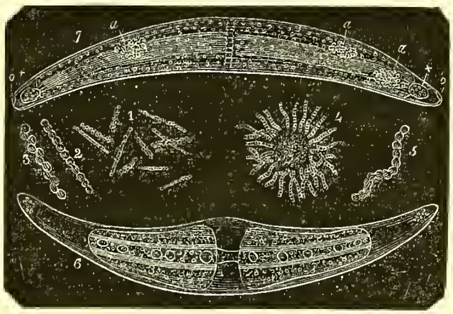
It is easy to prove by flattening the Volvox between two plates of glass that its interior is only filled with water, in which sometimes there may be observed smaller volvoces swimming about, the products of the propagation of some of the constituent animalcules. These are not solitary young ones, but may already be seen to be composed of numerous individuals, formed by the continual division of the original from which they sprang.

Another mode of reproduction is by the laceration or division of the globe itself. When this takes place, either for the escape of the included Volvoces generated within, or from any other cause, the component Monads immediately prepare to leave their domiciles, and the individual animalcules become separated by the dissolution of the inter-communicating threads; they then, by little and little, extricate themselves from the common gelatinous envelope, and creep out to commence an independent existence. The gelatinous polypary of the original Volvox in consequence speedily loses all its green spots; and as every little point is active, moving its proboscis freely when it leaves the common globe, it may fairly be concluded that they have a power of independent existence, and that each is able to begin the construction of another compound Volvox as wonderful as that we have been considering.

The developement of the embryo of the Volvox is represented in 11, 12, 13, *fig.* 1. In 11, *fig.* 1, is represented the simplest condition of a granular mass containing a clear central spot, which in the course of a few hours assumes the condition represented in 12, *fig.* 1, by undergoing an imperfect spontaneous division. By a continued repetition of this division it becomes at last broken up, until it has the appearance shewn in 13, *fig.* 1. The component vesicles still go on subdividing, until it assumes the appearance of a single perfect Monadine possessed of two proboscides, eye-spots, &c. By a further developement it constructs for itself an external envelope, which has the appearance of a white ring surrounding the central nucleus.

Wonderful as is the organisation of the last family, it would probably not be more so than that of the Vibrionidæ, was it in our power to display their internal economy in an equally satisfactory manner; but such is the extreme minuteness of all the members of the family, that even to Ehrenberg this seemed a hopeless wish. The Vibrionidæ present themselves under the microscope as thread-like bodies of indescribable tenuity, worming their way in countless thousands through the drop of water in which they live, and presenting themselves in different shapes, which have been classified as belonging to five distinct genera, named as follows:—The first, *Bacterium*, contains those forms which exhibit the appearance of stiff-jointed filaments. In the second, *Vibrio*, the

Fig. 5.



1, 2, 3. *Vibrio subtilis.* 4. *Vibrio rugula.* 5. *Vibrio rugula more highly magnified.* 6. *Closterium moniliferum.* 7. *Closterium turgidum.*

a, *a*, *a*, three large aggregations of living corpuscles; x, x, the locomotive papillæ; *o*, *o*, openings in the shell.

creatures resemble minute chains, which seem to be as soft and flexible as the body of a serpent, although so exceedingly minute that some species have been calculated to be not more than the 300th of a line long, and the 3000th of a line in thickness.

The animalcules in some genera assume the appearance of tortuous chains or flexible spiral threads. In *Spirillum* the body seems rolled into a stiff spiral cylinder, and in *Spirodiscus* it is arranged in a kind of disc.

On examining these little beings while alive, little doubt can be entertained that they belong to the animal series of creation: the manner in which they obviously direct their course at will, and the facility with which all their movements are performed, have caused them to be recognised as animals by all observers. It is, however, to Ehrenberg that we are indebted for the discovery of their real nature. From his observations we learn that these living filaments, minute as they are, are not single animals, but chains composed of numerous associated individuals produced from each other by spontaneous fissure. There even seems to be reason to suspect that their internal structure is in some degree allied to that of the Monadines; at least in one species, *Bacterium triloculare*, Ehrenberg perceived a proboscidiform mouth similar to that possessed by the Monadines of Volvox.

The peculiar forms assumed by the different genera of Vibrionidæ seem to depend upon the character of the fissiparous division by which the whole chain is produced, the compound body remaining straight or becoming thrown into spiral folds as the division is equably or unequably carried on.

The snake-like movements of the true Vibrios during their progress in the water, Ehrenberg conceived to be produced by a power of contracting forcibly, that resides in the individual

segments of the compound body, which enables them to change their situation relative to each other.

In the next family, *Closterium*, (6, 7, *fig.* 5,) the locomotive organs present themselves under a very different aspect, as, indeed, do the animalcules themselves. The animalcules are incased in a thin, transparent, shuttle-shaped shell, or mantle, *(urceolus,)* which is in many species evidently open at both ends. Enclosed in this shell is the exceedingly soft and transparent mucus-like body of the animal, which is frequently entirely full of green-coloured granules and little vesicles. The shell or mantle, when exposed to heat, is reduced to ashes and entirely volatilized, crisping up during the process like horn.

The locomotive apparatus is exceedingly singular in its conformation; it consists of numerous very short, delicate, transparent organs, having the form of conical papillæ: these are situated in the neighbourhood of the two openings in the mantle, lying in the inner space, and can be protruded externally to a short distance. It becomes evident, on mixing a few coloured particles with the fluid in which the animal is contained, that these are instruments of locomotion.

The family *Astasia* (1, *fig.* 6) contains numerous genera remarkable for the contractile power of their bodies, which causes them continually to change their shape, and consequently they become very puzzling objects to the inexperienced microscopist. Many of them are exceedingly beautiful on account of their rich colours; and so enormously do they abound under certain circumstances, that the water in which they are found is changed to red, green, or yellow, in accordance with the tint of the species which multiplies therein. In many species of this family, contractile proboscides have been found to exist, which most probably form the locomotive apparatus common to the group. Animals very similar to the Astasians, but loricated, constitute the family *Dinobryina*, (6, *fig.* 6,) the envelope forming an urceolus, in which the highly contractile body of the animalcule is lodged, having much the appearance of a microscopic *Sertularia*.

In the next family, *Amoeba*, locomotion is accomplished in a most extraordinary manner, these animals apparently possessing the power of making foot-like processes for themselves, or dispensing with them altogether, just as circumstances render it convenient. The *Amoeba*, or *Proteus*, as it was formerly named on account of the facility with which it changes its form, seems to have its body composed of a greyish mucus-like jelly, the shape of which is perpetually changing, sometimes shrinking into a rounded mass, then extending itself in all directions as though it was entirely fluid, or shooting out processes of different kinds from any part of the periphery of its body: its movements indeed seem to be rather fluent than progressive, so easily dees it mould itself to any required form. It is, nevertheless, very voracious, and its shape is frequently found to be modified by the contour and dimensions of other animalcules which it may have swallowed. (7, 8, 9, 10, 11, 12, 13, *fig.* 6.)

Fig. 6.

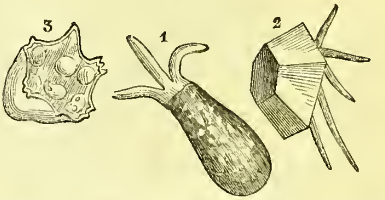
1. *Astasia flavicans.* 2. *Amblyophys viridis.* 3. *Euglena acus.* 4. *Chlorogonium euchlorum,* 5. *Colacium stentorum on a portion of the leg of a monoculus.* 6. *Dinobryon sertularia.* 7, 8, 9, 10, 11, 12, 13. *Amoeba diffluens,* exhibiting a few of its changes of form.

The genera Difflugia, Arcella, and Cyphidium (1, 2, 3, *fig.* 7) seem to be merely Amoebæ endowed with a power of constructing for themselves a carapax or shelly covering of various forms, from the orifices of which the fluent body of the animalcules can be made to protrude, and thus become convertible into instruments of locomotion.

In *Cyclidium*, *Pantotrichum*, and *Chætomonas*, and their loricated representatives, *Chætotypla*, *Chætoglena*, *Peridinium*, and *Glenodinium*, forming the families Cyclididæ and Peridinaeadæ, we first find a new system of locomotive organs making their appearance in the shape of vibratile cilia.

The locomotive cilia are variously disposed in different genera; sometimes they are disseminated over the entire surface of the animal, either irregularly or arranged in regular rows; sometimes they are only partially distributed or are confined to the region of the mouth and anterior part of the body; but, whatever their situation, their action is similar; they are incessantly in a state of active motion, either propelling the animalcule through the water, or causing currents to flow in definite directions, by the agency of which food is brought to the oral opening.

Fig. 7.

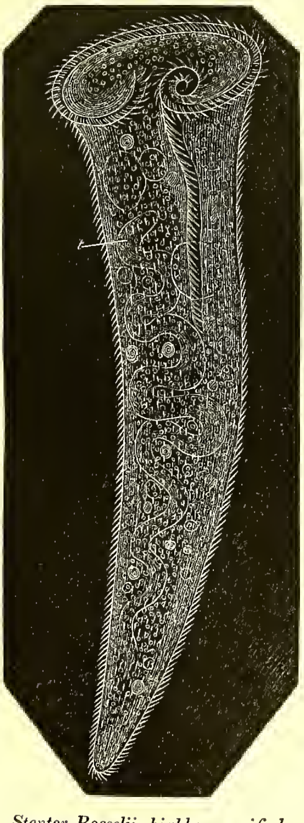


1. *Difflugia oblonga.* 2. *Arcella dentata.* 3. *Cyphidium aureolum.*

The genus *Stentor (fig.* 8) contains some of the largest and most active animalcules belonging to the class, and, as might be expected, these are amongst the most conspicuous for the perfection of their locomotive organs. These beautiful creatures resemble gelatinous trumpets, the bodies of which are flexible and contractile in all directions, either while swimming about freely in the water, or while attached, as they frequently are, to some foreign body by means of a little sucking disc which terminates the pointed extremity of the tail.

The whole of the trumpet-shaped body of Stentor is covered over with innumerable cilia, disposed in regular rows, and of sufficient size to be easily distinguishable by the microscope. Its broad end is terminated by a circular disc, the diameter of which is considerably larger than the widest part of the body. The entire surface of this disc is likewise covered with multitudes of cilia, arranged in regular concentric circles; and, moreover, its margin is fringed all around with a single row of cilia of larger dimensions, which by the rapid succession of their movements give the appearance of a wheel spinning rapidly round, and by its revolution causing powerful currents in the surrounding water. At the lower part of the margin of the ciliated disc the ciliary zone turns inwards, forming a spiral fold around a funnel-like aperture *(fig.* 8) which leads to the mouth, and likewise lodges the orifice through which digested materials are cast out. The currents caused by the marginal fringe around the disc are all directed towards the oral aperture, and consequently, by bringing nutritive particles to the mouth, this part of the apparatus becomes eminently subservient to nutrition. In several species of Stentor, in addition to the apparatus of cilia described above, there is an additional riband-shaped band of these vibratile organs extending from near the mouth to a considerable distance towards the hinder part of the body, the outline of which has an undulated appearance.

Fig. 8.



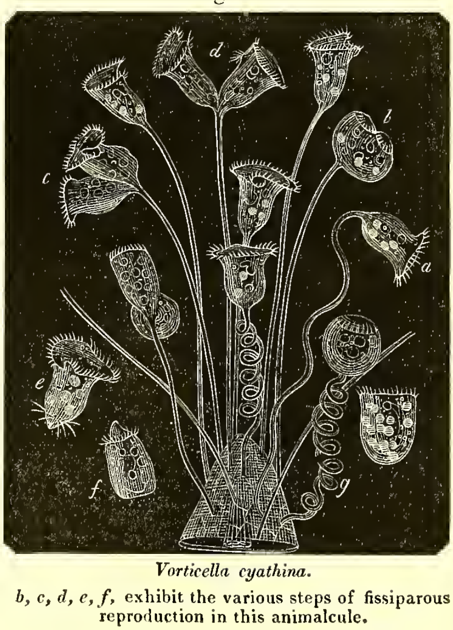
Stentor Roeselii, highly magnified.

t, viscus supposed by Ehrenberg to be the testis.

The Trichodinæ, or Urn animalcules, have no pedicle or elongated tail, but are provided with a fasciculus or circlet of cilia situated in front of their bodies, which are disc-shaped, bowl-shaped, or conical, the mouth being apparently a single orifice situated in the ciliary circlet. One species of this group, T. pediculus, seems to be parasitically attached to the Hydra viridis, and allied forms have been met with in the respiratory laminæ of several bivalve shell-fish, *(Anodonta, Unio,* &c.,) and also in Gyrodactylus coronatus, itself a parasite inhabiting the gills of the Crucian Carp *(Cyprinus Carassius).* That these animalcules are really Polygastrica, and not sterelminthous entozoa, Ehrenberg satisfied himself by feeding them with indigo. *Urocentrum* seems to be similarly organized, only it is furnished posteriorly with a sharp style-like process.

But perhaps the most remarkable as well as most elegant of all the forms of animalcules belonging to this group are the *Vorticellæ, (fig.* 9,) the sight of which cannot fail to exact the untiring admiration of the microscopical

Fig. 9.



Vorticella cyathina.

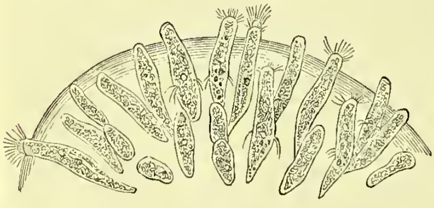
b, c, d, e, f, exhibit the various steps of fissiparous reproduction in this animalcule.

observer. These beautiful little creatures might be compared to wine-glasses of microscopic dimension, the bells of which are fixed to highly irritable stems, that are attached by their opposite extremity to some foreign body. These stems are endowed with the capability of extending themselves in the shape of straight filaments of exquisite tenuity, and on the slightest alarm or irritation, of shrinking into close spiral folds, so as to draw the little bell as far as possible from danger. The mouth of the bell is fringed with a circlet of cilia, which vibrate rapidly at the pleasure of the animal, causing a magnificent whirlpool in the surrounding water, which brings nutritious substances that may be in the neighbourhood towards the oral orifice, the situation of which is nearly the same as in Stentor, above described, and thus the little being is abundantly supplied with food. The true Vorticellæ, although generally found grouped together in elegant bunches, always have single undivided stems; but in the genus *Carchesium*, the animals of which are similarly organised, the pedicles sprout from one another so as to have a branched or ramose appearance, while in the genus *Epistylis*, animals similar to Vorticella and Carchesium are met with, the stems of which are quite stiff and inflexible, so much so indeed that the animalcules belonging to this group have obtained the name of "pillar bells" (*Saulenglöckchen*).

The family *Ophrydinidæ* presents us again with very remarkable forms of Polygastric animalcules, allied in structure to the Vorticellæ, but having their bodies inclosed in cases of different kinds, of which it will be necessary to give one or two examples.

The genus *Ophrydium*, (jelly-bell-animalcules,) of which the Ophrydium versatile (*fig.* 10) is an example, was regarded by the older

Fig. 10.



Section of a portion of the periphery of Ophrydium versatile, showing the manner in which the individual animalcules are implanted in the mass.

naturalists as being a mass of vegetable matter, and had the names of ulva, fucus, conferva, &c. conferred upon it by different authors, until Müller, in 1786, first announced its real nature and relationship to the vorticelline animalcules. It is found under the shape of a gelatinous mass of a lively or dull green colour, which in consistence may be compared to frog's spawn, some specimens attaining the size of four or five inches in diameter; the whole forming an irregularly shaped but smooth mass, which is composed of many millions of distinct animalcules, each about $\frac{1}{96}$th of a line in thickness, and about the $\frac{1}{10}$th of a line in length. The space of a square line would therefore contain 9216 of these diminutive beings; a cubic line six times as many, or 55,296; and a cubic inch nearly eight millions, namely, 7,962,624. In the water all these congregated animalcules are disposed in close rows, something in the same manner as in Volvox. On shaking the mass many others show themselves within between the former, so as to form from three to five different ranks. At first all the gelatinous cells appear to be connected with the centre of the mass by filamentary prolongations, but these disappear as they proceed internally, so that the middle seems to be hollow and full of water; the whole, indeed, might be compared to the gelatinous polyp masses (*Alcyonidæ*) found upon the sea-shore, only the structure of the animalcules is polygastric and not that of polyps.

In the other genera belonging to the family Ophrydinidæ, namely, *Tintinnus*, *Vaginicola* (9, *fig.* 11,) and *Cothurnia*, although living in gelatinous transparent sheaths, and resembling Vorticellæ in their structure, are not associated in masses, but remain permanently detached and solitary.

The family Encheliadæ contains various forms of animalcules, having the oral and anal orifices distinct and situated at the opposite extremities of the body. The different genera of which it is composed may be distinguished as follows:—

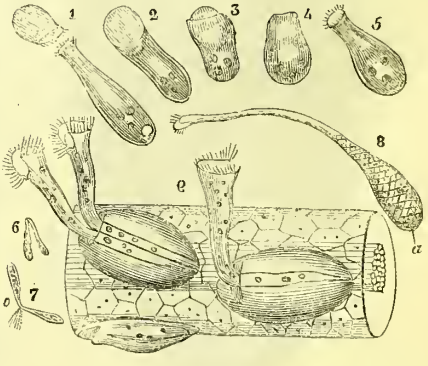
Enchelis, (*revolving animalcule,*) has its body flask-shaped, (1, *fig.* 11,) without any cilia externally, but with a circlet around the mouth, which is suddenly truncated and destitute of any dental armature.

Disoma, (*double-bodied animalcule,*) creatures nearly resembling Enchelis in form and structure, but with a double body (6, 7, *fig.* 11).

Actinophrys, (*sun animalcule,*) having the exterior of the body unprovided with locomotive cilia, but stuck over with setaceous tentacula which radiate in all directions.

Trichodiscus, (*radiated disc animalcule,*) resembling Actinophrys, only the body is here

Fig. 11.



1, 2, 3, 4, 5. *Enchelis farcimen, swallowing food.* 6, 7. *Disoma vacillans.* 8. *Lachrymaria proteus.* 9. *Vaginicola decumbens.*

compressed, and only furnished with a single row of setaceous tentacula, situated around its margin.

Podophyra, (radiated foot animalcule,) is an Actinophrys with a spherical body, from which projects a long straight pedicle, which, however, is not attached to any foreign body.

Trichoda, (hair animalcale,) an Enchelis having its mouth obliquely truncated and furnished with a lip; its body is unprovided with a neck-like prolongation.

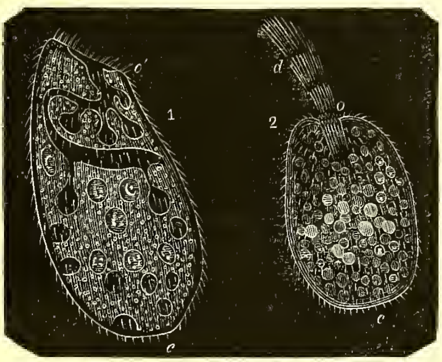
Lachrymaria, (lachrymatory animalcule,) (8, *fig.* 11,) an Enchelis having its body destitute of cilia externally, but terminated by a long thin neck, which is clavate at the extremity, and ends with a mouth provided with a lip and ciliated margin.

Leucophrys, (ciliated animalcule,) an Enchelis, with its body entirely covered with vibratile cilia—its mouth is obliquely terminal and provided with a kind of lip, but without dental organs. (1, *fig.* 12.)

Holophrya, (woolly animalcale,) an Enchelis having the exterior of its body entirely ciliated.

Prorodon (toothed rolling animalcule). In this genus, like the last, the body is covered all over with vibratile cilia, and the mouth

Fig. 12.



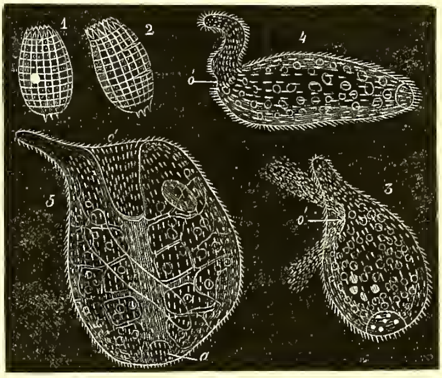
1. ***Leucophrys patula.*** **2.** ***Prorodon teres.***
ŏ, mouth; c, outlet of alimentary tube.

truncated, but the latter is remarkable for being armed with a circlet of teeth of a very peculiar structure situated within its margin. (2, *fig.* 12)

The family Colepinidæ consists of but one genus, *Coleps* (1, 2, *fig.* 13), the animalcules belonging to which have all the characters of Enchelis, except that they are loricated. These animalcules are found among confervæ, more especially in summer time. As long as they are swimming it is difficult to perceive the transparent case in which they are enclosed; but if they are allowed to get dry or are crushed between two plates of glass, its presence becomes manifest as well as its brittleness. In shape this external covering resembles a little barrel made up of rows of plates or rings, between which the cilia seem to be exserted *(testula multipartita).* Anteriorly it is truncated, its margin being either smooth or toothed, and posteriorly terminates in three or five little sharp points.

The next family, *Trachelinidæ*, contains all those non-loricated animalcules whose alimentary canal has two distinct orifices, but of which one only, the anal, is terminal. The genera that belong to it are very interesting objects, and many of them of great beauty. The reader

Fig. 13.



1, 2. ***Coleps hirtus.*** **3, 4.** ***Trachelius anas.*** **5.** ***Trachelius ovum.***
ŏ, mouth; a, outlet of alimentary canal.

will be able readily to recognise them by the following characters:—

Trachelius (neck animalcales, 5, *fig.* 13). These may be readily known by their excessively elongated upper lip, which has the appearance of a long proboscis, or rather, perhaps, resembles the neck of a goose or swan, from which circumstance some species *(Trachelius anus)* have received their best known appellations. Attentive examination, however, shews that the mouth is situated at the bottom of this neck-like prolongation (3, 4, *fig.* 13), and not at its extremity, as was the case in Lachrymaria. The body is ciliated over its entire surface; nevertheless the movement of some species is very sluggish, locomotion seeming rather to be effected by creeping and bending the body than by the exertion of the cilia. Some species are exceedingly voracious, as for example *Trachelius vorax*, figured by Ehrenberg, which is represented in the act of swallowing a Loxodes Bursaria, of which six may be seen already lodged in the interior of its body.

Loxodes (lip animalcules). These have not the neck-like appendage of the last genus, but have the upper lip dilated and hatchet-shaped.

Bursaria (purse animalcules). In these the mouth is very wide and placed laterally, with very capacious prominent lips, but without any dental structure. They are very voracious, and although generally met with in water, some species, viz. *B. Entozoon*, *B. intestinalis*, and *B. cordiformis*, live parasitically in the intestines of the frog, toad, and water-newt.

The genera *Spirostomum (snail animalcules)*, *Phialina (spigot animalcules)*, *Glaucoma (pearl animalcules)*, are too nearly allied to the preceding to render any special account of them necessary.

The genus *Chilodon* presents a very similar organisation, but is remarkable from the circumstance that its mouth is furnished with a tubular fasciculus of setaceous teeth, while the anterior part of its body is advanced forward in the shape of an expanded membrane or prolonged on one side, so as to form an auriculated appendage. In *Nassula*, likewise, a similar dental structure exists, but this will be best described hereafter.

Nutritive system.—By employing coloured organic substances as food for these animalcules, Ehrenberg at length succeeded in developing the organisation of the nutritive apparatus in these microscopic beings. For this purpose he made use of pure indigo, carmine, sap-green, and other vegetable colouring substances which are insoluble in but miscible with water, very finely levigated, and which the animalcules readily swallow, so that in a few minutes the coloured particles are distinctly visible in the interior of their transparent bodies.

From observations conducted in this manner the following results were obtained:—1st. That there is no absorption of the coloured fluid through the general integument of the bodies of infusorial animalcules, although this was formerly supposed to be the only manner in which they could be nourished; but, on the contrary, that they were all furnished with a special mouth and internal nutritive apparatus.

2nd. That the smallest species of Infusoria which can be observed with our instruments, even those not more than $\frac{1}{1500}$ of a line in length, have an internal set of nutritive organs as well as the largest, so that in the Monads even four, six, or eight sacculi are visible in the interior of the body, which are obviously filled through an oral aperture.

In the genera Enchelis, Paramecium, and Kolpoda, moreover, an intestiniform tube was discovered traversing the whole length of the body, and opening by a distinct anal orifice. To this central canal are appended numerous blind vesicles, giving the whole apparatus the appearance of a bunch of grapes. In *Paramecium aurelia* and *Paramecium chrysalis* Ehrenberg counted from one to two hundred of these vesicles, which became filled with blue, red, or green, according to the colouring matter employed.

We have, however, already, in the preceding pages, described the different arrangement of the alimentary canal in the various forms of polygastric animalcules, so that few further observations are necessary in this place. Whoever wishes to observe these little beings swallow coloured food, and thus witness the filling of the nutritive sacculi, must, in order to avoid disappointment, carefully observe that the materials he employs are perfectly pure, the indigo, carmine, and sap green sold in the shops being generally so much adulterated that the animalcules refuse to swallow it; secondly, that it be reduced by levigation to the most extreme state of division—grinding it for a length of time with water on a slab, with a muller, is the best way to accomplish this. When thus prepared, by placing a little with a camel's hair brush in the drop of water which contains the animalcules, but very few minutes are required with some species to exhibit numerous vesicles filled with the coloured substance. When filled, Ehrenberg has observed that sometimes one of them will in a short time empty itself, and its contents be suddenly transferred to another, whereby it seems as if the vesicle itself had a power of voluntary locomotion, which it has not. But however easy it may be thus to fill the stomachal vesicles, it is by no means so easy a matter to detect the central canal to which they are appended, insomuch that the generality of observers are quite unable to detect its presence. Upon this point Ehrenberg remarks, in reply to those who have doubted its existence, that there are only some animalcules in which it is possible to see it clearly; and it is therefore necessary to seek out such species in order to obtain a view of it. In many it is of all things most difficult to see it; but the cause of this does not lie in its absence, but in the nature of the functions it has to perform, for this canal, like the œsophagus of larger animals, only serves for the transmission of food, not for its retention and digestion. It becomes dilated while food is passing through it, at will, like the mouth and œsophagus of a snake when it swallows a rabbit, and immediately collapses again, and becomes quite invisible when not actually in use.

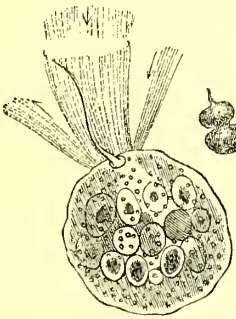
Provided the indigo and carmine employed for the purpose have been sufficiently levigated, nothing is easier than to demonstrate the presence of the stomachal vesicles; but to exhibit the central canal, and the tubes that communicate between it and the gastric sacculi, is a much more difficult task, and can only be done under very favourable circumstances. We were, indeed, long sceptical concerning their existence; but after examining Professor Ehrenberg's preparations of these structures, we were ultimately convinced of the accuracy of his views concerning them.

Whoever wishes to see the intestinal tract distinctly must examine it in large specimens of some of the following species, most of which are sufficiently common:—*Chelodon cucullulus*, *Trachelius ovum*, *Epistylis plicatilis*, *Vorticella chlorostigma*, *Vorticella convallaria*, *Opercularia articulata*, or *Stylonychia mytilus*. On putting a little indigo into the water with some of these, it may be readily seen to enter their large mouths, and pass into their stomachs, from which it is again speedily ejected.

In the Monads and allied families the alimentary apparatus consists of several distinct cells, from eight to twenty in number, but which are not all of them filled at the same time. When contracted they are quite invisible; yet sometimes, when filled with a clear fluid, they are to be distinguished under the form of minute transparent vesicles in the interior of the animalcule. The mouth may sometimes be easily perceived under the form of a clear transparent spot, situated at the base of the proboscis, to and from which streams of water may be seen to proceed, bringing

with them the materials for nourishment (*fig.* 14). In the interior of the body the nutritive sacculi appear like so many little empty bags hanging from the mouth. The food of the Monads seems to consist entirely of particles of decaying matter.

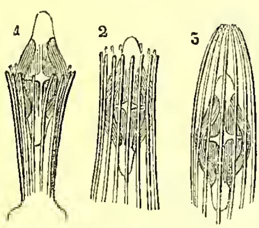
Fig. 14.



Monas guttula, highly magnified, showing the direction of the nutritive currents.

Dental system.—A very remarkable dental apparatus was discovered by Ehrenberg to exist in some of these diminutive beings, their presence being recognised in several different species, viz. *Euodon cucullus* (Synonyme, *Kolpoda, Loxodes cucullus), Nassula ornata, Nassula elegans, Nassula aurea, Prorodon niveus, Prorodon compressus*, and others. Both in their form and connexions these teeth are very remarkable, presenting the appearance of a long slender cylinder or hollow cone, situated at the entrance of the mouth, around which they form a closely approximated series (*fig.* 15). These teeth

Fig. 15.

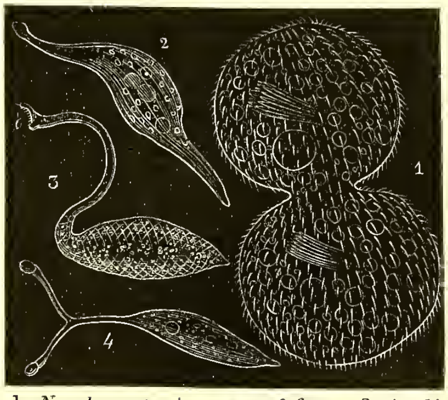


Dental apparatus of Chilodon ornatus. (After Ehrenberg.)

are composed of a hard substance; for when the soft parts of the animalcule are crushed between two plates of glass, they still remain distinctly visible, proving that they are of a denser texture than the rest of the body. Their number varies in different genera from sixteen to thirty, the former being the minimum and the latter the maximum yet observed. In animalcules thus provided with a dental apparatus the pharynx seems to have little to do with the act of nutrition; indeed it frequently happens that while the little creature vibrates its cilia to produce the currents that bring it food, its mouth is kept open and motionless, so that the materials that serve for its nourishment pass through it unobstructed: but when larger morsels are to be swallowed, they are first seized and bruised by the dental apparatus. In this case the buccal cylinder first of all expands in front to receive the morsel; it is then narrow posteriorly: but as the aliment passes onward it becomes contracted in front and dilates behind, so as to push the food towards the mouth. Sometimes, however, these movements can be witnessed without any large morsels of food being present in the dental cylinder. While the mouth is kept open, Monads and other animalcules may frequently be seen to enter it with facility as far as the intestine; in which case the contraction of the dental circlet seems to serve to prevent its return back again, should it try to escape in this direction.

A very remarkable circumstance observable in these teeth is the rapid manner in which new sets are formed as often as the fissiparous habits of the animalcules render their reproduction necessary. This regeneration of whole sets of teeth, a phenomenon so unusual among other races of animals, is among these Infusoria a matter of every day occurrence, a new set being produced whenever spontaneous division occurs: nay, should the animalcule be mutilated so that only the hinder half of its body remains, we are assured by Ehrenberg that the missing portions will soon be reproduced, provided with a new mouth and circle of teeth exactly similar to their predecessors; and when they spontaneously divide by transverse fissure, a process which occupies but a short space of time, the hinder portion, when separated, is found to be provided with a mouth and set of teeth completely organised in every respect (1, *fig.* 16). Sometimes, indeed, they may be observed during this separation of the adult animal into two young ones, and the progress of the developement of the wanting parts absolutely witnessed. Under such circumstances Ehrenberg states, that such is the rapidity of the process that the division of the body, and the formation of a set of twenty new teeth, may easily be accomplished in the space of a couple of hours.

Fig. 16.



1. *Nassula ornata, in progress of fissure.* 2. *Amphileptus fasciola.* 3. *Trachelocerca viridis.* 4. *Trachelocerca biceps.* (*After Ehrenberg.*)

Muscular system.—In the generality of those

acrite animalcules it is almost needless to say that no muscular fibres are obvious, although their bodies are capable of various contortions, and some of their movements under the microscope are extremely brisk and active. Nevertheless, in some of the Vorticellinæ, (Vorticella, Stentor, Carchesium, Opercularia,) Ehrenberg considers that their presence has been detected, and has even assigned their direction, some being, as he asserts, longitudinal and others transverse. In the stems or pedicles of Carchesium and Tintinnus this appearance of muscular fibre is more especially evident; and when we consider the highly organised condition of the genera in question, there seems to be no physiological reason for considering their existence improbable.

Nervous system and organs of sense.—No nervous fibrils have as yet been discovered in any polygastric animalcule, and, in accordance with this acrite condition, no special instruments of sensation could, according to all physiological analogy, be expected to exist; nevertheless, in many genera the existence of one or two minute spots of a brilliant red colour is conspicuous, which are invariably found to occupy the same position in a given species possessed of them. These red spots are generally pronounced to be eyes, although for what reason, except that they correspond in colour with the acknowledged eyes of some of the lowest forms of the Articulata, it is difficult to conjecture. In two species indeed, (*Euglena longicauda* and *Amblyophys,)* Ehrenberg says he saw a " clear sharply defined ganglion," (einen hellen, scharf umgrenzten Markknoten,) under the red eye-spot, without, however, offering the slightest proof that the " clear sharply defined body " in question was composed of nervous matter. Should, however, Ehrenberg's surmises, (for these assertions are nothing more,) be correct, we should indeed encounter in the Infusoria an apparatus of vision of the simplest possible description, consisting merely of a brain and a coat of coloured pigment, thus dispensing both with the refracting media that usually constitute an eye, and the nervous communication generally found between it and the brain. Be this as it may, the Polygastria are evidently possessed of considerable perceptive power, (those without red spots quite as much so as those provided with them;) however rapid their movements, they can steer their course with accuracy, and avoid impinging against each other; they can likewise perceive the slightest contact, and some species, such as the Vorticellinæ for example, exhibit a most exquisite sensibility of touch.

Secretions.— Several species of Polygastria secrete a peculiar fluid of a beautiful violet colour, which is poured into the intestinal canal, where it colours the excrements with which it is expelled from the body. In *Nassula ornata*, (1, *fig.* 16,) the apparatus for secreting this fluid is situated at the anterior part of the body, where it is recognisable as an irregular square spot of a violet colour, situated upon the dorsal surface of the body immediately opposite to the dental cylinder. This spot is composed of a great number of little violet globules of unequal size, or, to speak more correctly, of an aggregation of colourless vesicles filled with a violet-coloured fluid. From this spot a canal may be traced running along the back, resembling a string of pearls, in which the violet secretion is conveyed towards the posterior part of the body. It is only in the posterior third of the body that there seems to exist a direct union between this canal and the alimentary apparatus, for at this point the violet colour of the secretion becomes altered and mixed with foreign matter. In all these Infusoria the violet secretion is expelled through the anal orifice situated at the hinder part of the body, either by itself or in conjunction with the excrements. The aggregation of vesicles situated in the back of the neck seems to be the secreting organ of this remarkable fluid, seeing that no vessels could be detected in communication with it, and the surrounding parts were quite transparent and colourless. Ehrenberg believes that the violet liquid, which is of a slightly viscid or almost oily character, possesses some dissolving power, for he has noticed in the alimentary canal of animalcules which contained a large proportion of it, that fragments of oscillatoriæ and other substances taken as food were always discoloured, divided, or decomposed apparently by its action.

Reproduction.— Not the least remarkable feature in the history of the Polygastria is their extraordinary fecundity, which indeed far exceeds that of any other class of animals. The infusorial animalcules, constituting as they do the basis of the great pyramid of the animal creation, the living pasturage diffused through the waters of our globe, on which innumerable creatures have to feed, must be multiplied in proportion to the vast demand for food of this description; and, accordingly, their multiplication is effected in various ways, all of which are so prolific that it becomes no longer a matter of astonishment that they swarm to such an extent in every drop of stagnant water, or that their exuviæ are found in many localities accumulated in such abundance, that strata of soil and even vast rocks seem to be entirely composed of their remains.

Fissiparous generation.—This mode of reproduction consists in the spontaneous fissure of the original animalcule into two or more divisions, each of which soon becomes complete in all its parts, and again divides in a similar manner. The different steps of this process, which may easily be witnessed, are in ordinary cases as follows. The body of the parent is seen, on its arrival at maturity, to become intersected by a transparent line, which divides it into two equal halves. In a short time this transparent line becomes indented at each extremity, and, as the indentations become more pronounced, the original creature becomes evidently converted into two, which are united together by a kind of isthmus, (*figs.* 17 & 18) and at length, the isthmus becoming continually more and more attenuated, the slightest

effort, or the mere action of the vibratile cilia completes the operation, and the two young animalcules, thus formed, part company and commence an independent existence.

The direction of the line of separation varies in different species, and even in individuals of the same species (*fig.* 17. 4, 5, 6, 7, 8); sometimes it is transverse, sometimes oblique, and in other cases it traverses the long axis of the body, where the form of the animalcule is elongated or oval. This method of reproduction is exceedingly prolific; for, as each successive generation arrives at maturity in the course of a few hours, and undergoes the same process of division, it will be found on computation that the progeny derived from a single animalcule may, in the course of a single month, amount to many hundred millions in number.

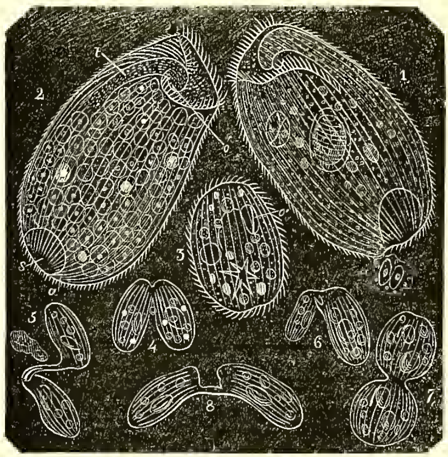
In the Vorticellæ and allied forms supported by rigid or flexible pedicles the fissiparous process is essentially similar. The adult bell (*fig.* 9, *a*) preparatory to its division becomes considerably extended in a lateral direction (*b*), in which condition the line of fissure is indicated, extending from the mouth of the bell to the point of its connection with the pedicle. An indentation soon appears which, progressively extending downwards, soon separates the original animalcule into two, both of which are attached to the stem (*c*, *d*). In a short time one or both break loose; in the former case the stem survives, in the latter it perishes. The detached bells speedily assume a new form (*e*, *f*), and might easily be mistaken for a totally different genus swimming about by means of cilia situated at both extremities of their barrel-like bodies. At last, having found a fit support, they fix themselves to it, the attached extremity becoming gradually elongated into a delicate irritable filament similar to that which they possessed prior to the commencement of the fissiparous process.

Gemmiparous reproduction. — Besides the above mode of increase, many of the Vorticellæ and similarly organized forms throw out little gemmæ or lateral buds in the same manner as the Hydræ and some other Polypes, which, as they advance to maturity, assume the form of the parent stock, from which they at length become detached, or else remain associated with the original from whence they sprung.

Sporiferous reproduction. — The gastric vesicles of the Polygastria occupy but a small proportion of the interior of their minute bodies; the rest is partially filled up with a granular tissue, which seems made up of nucleated cells, or, in other words, of sporules or spawn, the germs of future progeny ready to be called into active existence when liberated from the nidus in which they were generated. In Kolpoda cucullus (*fig.* 18, 3), these sporules are represented in the act of becoming discharged from the parent animalculæ.

In many species of animalcules it is easy, with the assistance of a good glass, to perceive in the interior of their bodies certain isolated sacculi endowed with very remarkable powers of contraction and of dilatation; this is repeated at regular intervals; and so great is the contractile force that the little sac seems entirely to disappear, and then in a short time slowly dilating regains its former size. These sacculi Ehrenberg at first thought to be stomachal cavities, which the creature could alternately fill and empty; but subsequent observations convinced him that they were organs of a peculiar character. By slightly compressing large specimens, such as *Paramecium aurelia*, he further observed that these contractile vesicles were generally two (sometimes three) in number, occupying determinate situations in the creature's body, and that from each of these a number (eight) of little canals were given off like rays from a centre towards the circumference of the body. These canals became gradually enlarged as the sacculus contracted; and vice versâ, when the vesicle dilated the canals shrunk and disappeared. Each canal is slightly enlarged at its origin from the central cavity, and the whole apparatus has the appearance of two little *Ophiuri*, or thin-rayed starfishes, enclosed in the body of the animalcule (*fig.* 18, 1 & 4, s, s). The contractile sacculi were seen by Ehrenberg in at least four-and-twenty different species of Polygastrica; but the radiating canals were detected in two only, viz. *Paramecium* and *Ophryoglena*.

Fig. 17.

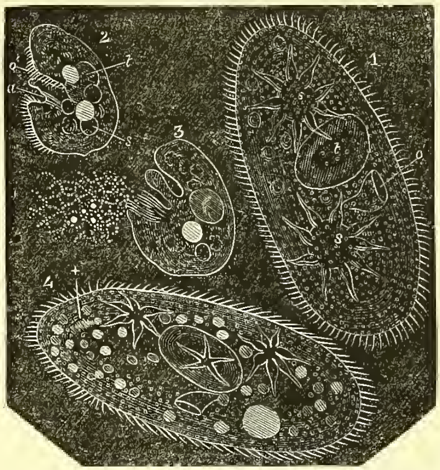


1, 2. *Spirostomum virens.* 3. *Glaucoma scintillans.* 4, 5, 6, 7, 8. *Glaucoma scintillans in progress of fissiparous reproduction, showing its different modes of fissure.* (*After Ehrenberg.*)

These organs exhibit, both in their number and situation, important differences in different species. In *Paramecium aurelia*, *Paramecium caudatum*, *Leucophrys sanguinea*, *Trachelius anas*, *Bursaria vernalis*, and *Stentor Mulleri*, two of them are found, one situated in the middle of the anterior, and the other in the middle of the posterior, halves of the animal. All the above species, with the exception of *Stentor*, multiply by spontaneous transverse division, and when thus divided each portion retains one of the contractile organs, and their being thus double seems to have some relation

with the kind of fissiparous division which the animalcules undergo. At certain periods four of these sacculi are met with in several of these Infusoria, whilst at others only two are found in animalcules of the same species. When four are present, there are always two situated in each half of the body, and it is remarkable

Fig. 18.

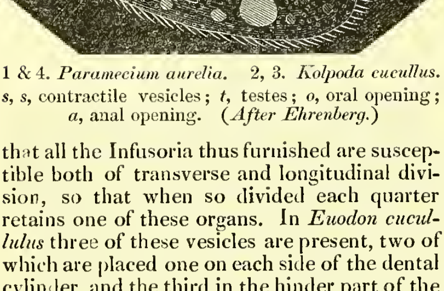


1 & 4. *Paramecium aurelia.* 2, 3. *Kolpoda cucullus.* *s, s,* contractile vesicles; *t*, testes; *o*, oral opening; *a*, anal opening. (*After Ehrenberg.*)

that all the Infusoria thus furnished are susceptible both of transverse and longitudinal division, so that when so divided each quarter retains one of these organs. In *Euodon cucullulus* three of these vesicles are present, two of which are placed one on each side of the dental cylinder, and the third in the hinder part of the body near a dilatation of the alimentary canal in the vicinity of the anal opening. This animalcule likewise divides both longitudinally and transversely.

There is another organ regarded by Ehrenberg as playing an important part in the organization of these Infusoria. This is of a roundish

Fig. 19.



Euplotes Charon, exhibiting its different modes of fissiparous generation. (*After Ehrenberg.*)

form, but less transparent than the contractile sacculus in the neighbourhood of which it is situated, but its presence has only been detected in four or five species. With respect to the functions to be ascribed to the parts above described, it is by no means easy to come to any satisfactory conclusion. Ehrenberg considers that the contractile organs provided with their radiating canals cannot be regarded as hearts because their movements are so slow; neither can he regard them as respiratory organs, which would require the presence of a vascular apparatus more distinctly developed than it appears to be in the Polygastric animalcules; he is, therefore, disposed to believe them to be connected with the generative system, and refers to them the office of fecundating the ova contained in the interior of the body by dispersing the seminal fluid.

The opaque body above described, the same authority suggests to be the testis, believing it to secrete a seminal fluid. Both these suppositions are based upon a fancied analogy between the parts in question and certain organs which are met with in the Rotifera, and it is needless to say that they are at present purely hypothetical. (*T. Rymer Jones.*)

POLYPIFERA. — A class of Zoophytes most extensively distributed over the surface of the globe, inhabitants both of the ocean and of fresh water, and important both on account of their numbers and of the magnitude of the structures raised by their agency. The most obvious character common to this vast race of animals is, that their mouths are surrounded by radiating tentacula, arranged somewhat like the rays of a flower; and hence the terms ZOOPHYTA, PHYTOZOA, and ANTHOZOA, have been more especially applied by naturalists to the members of this group of living beings. So plant-like, indeed, are the forms of many genera, that the ancients regarded all the stony polypes as stony vegetables, or as vegetating stones, and invented many theories to explain their growth. The earlier modern naturalists thought them plants, and even Tournefort has described twenty-eight species in his "Institutions of Botany;" but he was the last naturalist who committed this grave error. The animal nature of the Polypes was suspected by Imperato in 1669, was proved by Peyssonel in 1727, and shortly afterwards confirmed by Reaumur and Jussieu, the latter of whom, in 1741, added them to the animal kingdom.* In order to facilitate our investigations concerning the anatomy and physiology of so extensive a series of organized beings, it becomes imperative that we should first divide them into groups, composed of such genera as are most nearly allied by their structure and general habits, each of which will in turn require our separate notice.

CLASS. POLYPIFERA.

Sub-class 1. HYDROZOA.

Body gelatinous, free, naked, presenting internally a simple stomachal cavity, which is provided at its entrance with highly contrac-

* See the History of Zoophytology in Dr. Johnston's admirable "History of the British Zoophytes." Lond. 1847.

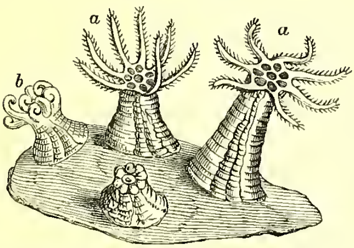
tile tentacular cirrhi; without traces of viscera, and reproduced by external gemmæ.

Hydra (*fig.* 25).

Sub-class 2. ANTHOZOA.

Mouth of polype flower-like, surrounded by contractile tentacula, the margins of which are

Fig. 20.



*Polypes of Cydonium protruded, magnified. (After Muller.)**

a, with the tentacles expanded; *b*, tentacles closed.

fringed, but destitute of vibratile cilia; stomach forming a distinct bag, without any intestinal canal; ovaria conspicuous, lodged in the interior of the body, beneath the stomachal cavity.

Family 1. — ALCYONIDÆ. Polypes distributed over the surface of a common mass, which is polymorphous, irregular, fleshy, adherent, and composed of a suberiform substance supported by calcareous aciculi.

Alcyonium, Lobularia, Cydonium.

Fig. 21.

*Cydonium Mulleri. (After Muller.)**

Family 2. — CORALLIDÆ. Polypes irregularly scattered, and more or less prominent upon the surface of a polype tree or common stem, which is arborescent, fixed by a basement, and composed of a solid, horny or calcareous axis enveloped by a sort of gelatino-calcareous living cortex.

Corallium, Isis, Gorgonia, Antipathes.

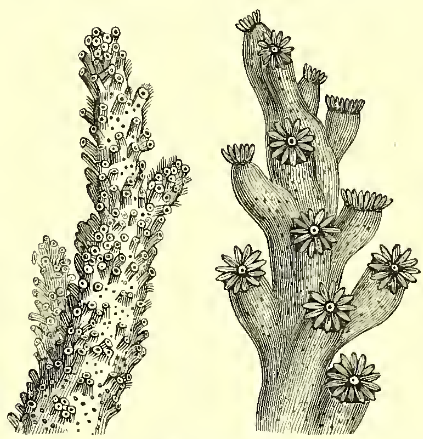
Family 3. — MADREPORIDÆ. Polypes inhabiting cells distributed over the surface of a stony polypary, which is fixed, and generally arborescent. The cells are small, sub-lamellated, and constantly porous in the intervals and in their walls (*fig.* 22).

* Zool. Dan. tab. lxxxi. *figs.* 3 & 4.

Dentipora, Astræopora, Sideropora, Stylopora, Coscinopora, Gemmipora, Montipora, Palmipora, Heliopora, Alveopora, Goniopora, Porites, Seriatopora, Pocillopora, &c.

Fig. 22.

A B

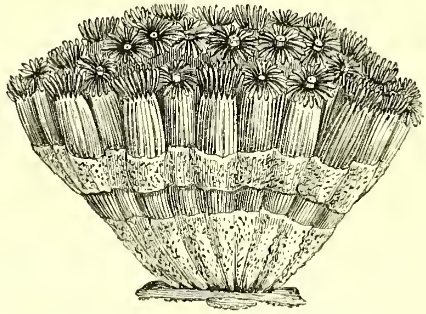


A, "Madrepore abrotanoide;" B, a portion magnified. (*After Quoy et Gaimard.*)

Family 4. — MADREPHYLLIDÆ. Animals simple or aggregated (in the latter case more or less deformed by their connection with those around them), and containing in their substance a great quantity of calcareous matter, forming a stony polypary, which is either free or fixed, and having a laminated surface, or provided with laminated cells.

Cyclolites, Montlivaltia, Fungia (*figs.* 38, 39), Polyphyllia, Anthophyllium, Turbinolia (*fig.* 41), Turbinolopsis, Caryophyllia (*fig.* 42), Sarcinula, Columnaria, Stylina, Catenopora, Seringopora, Dendrophyllia, Lobophyllia (*fig.* 23), Meandrina (*fig.* 40), Dictuophyllia, Agaricia, Tridacophyllia, Monticularis, Pavonia, Astræa (*fig.* 43), Echinastræa, Oculina, Branchastræa, &c.

Fig. 23.



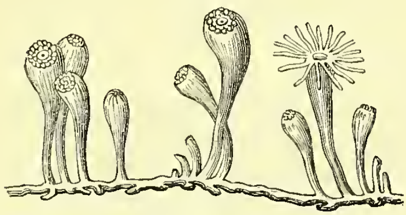
Lobophyllia angulosa. (After Quoy et Gaimard.)

Family 5. — ZOANTHIDÆ. Polypes more or less approximated, sometimes soldered together, encrusted, or solidified by foreign

bodies, and forming, when dried, a sort of coriaceous polypary.

Zoanthus, Mamillifera, Corticifera.

Fig. 24.



Actinia sociata (*Ellis*). *Zoanthus* (*Cuvier*). (*After Ellis.*)

Family 6.—ACTINIADÆ. Body soft and fleshy, free, mouth furnished with several rows of simple or branched tentacula.

Actinia (*fig.* 45) Lucernaria, Moschata, Actinecta, Discosoma, Actinodendron, Metridium, Thallasianthus, Actineria, Actinoloba, Actinocereus, &c.

Family 7.—PENNATULIDÆ. Animals polypiform, with eight pinnated tentacles, more or less prominent, and regularly arranged upon a part only of a common polypary, which is free or adherent. Its form is determinate, and it is composed of a central axis, which is solid, and enveloped in a fleshy cortex, often of considerable thickness, and supported by calcareous aciculi.

Pennatula (*fig.* 44), Renilla, Virgularia, Scirpearia, Pavoniaria, Veretillum, Ombellularia.

Sub-class 3. AULOZOA* (nobis). (Tubular Polypes.)

Animals simple or compound, occupying the interior of corneous or calcareous tubes, which are either simple or ramified; polypes terminal or lodged in lateral cells; reproduction multiform.

Family 1.—TUBULARIDÆ. Animals generally aggregated; polypes terminal, not retractile; reproduction by ova produced near the bases of the tentacula, and unenclosed in any cell; polypary pergamentaceous or corneous, simple, tortuous, or regularly ramified; sometimes wanting; tentacula, numerous, solid.

Tubularia (*fig.* 48.), Endendrum, Pennaria, Syncoryna (*fig.* 47), Coryna, Hydractinia, Stipula.

Family 2.—TUBIPORIDÆ. Polypary composed of calcareous tubes, arranged in successive stages like the pipes in an organ; polypes terminal, with eight pinnate arms.

Tubipora (*fig.* 52).

Family 3.—SERTULARIDÆ. Polypes hydriform, provided with simple tentacula, which are never ciliated; lodged in lateral cells of various shapes and disposition, continued into the interior of the tubular polypary, which is ramified, horny, subarticulated, and fixed by a root-like basis.

Sertularia (*fig.* 55), Campanularia.

* αὐλὸς, a pipe or reed; ζῶον, animal.

Sub-class 4.—BRYOZOA (Ehrenberg). *Ciliobrachiata* (Farre).

Animals polypiform, with the tentacula around the mouth covered with vibratile cilia, by the agency of which food is furnished to the oral opening; alimentary canal complete, being furnished with an intestine and distinct anal orifice; body generally enclosed in a corneous or calcareous cell; with or without an operculum.

Eschara (*fig.* 57), Flustræ, Bowerbankia (*fig.* 56), Pedicellina (*fig.* 65), Lagunculus (*fig.* 61), Cristatella Mucedo.

Polyps are invariably aquatic animals, some inhabiting fresh water, but the great body are marine, and most numerous in tropical seas. In very high latitudes only Cellarians, Sertularians, and Alcyons occur: and in the vicinity of volcanic islands in the polar seas Corallines and Gorgonians. These latter multiply a little from 6° to 9° N. Lat., and as they approach the tropics attain their full powers of growth and multiplication. Some frequent the mouths of rivers where there is a conflux of fresh and salt water; some love atmospheric influence, while others avoid it. The marine ones frequently plant themselves on rocks in different aspects, often regulated by the climate. They rarely expose themselves to violent currents, or the direct shock of the waves, being generally found in the hollows of rocks and submarine caverns, and in gulfs, where the water is less agitated.

HYDROZOA.

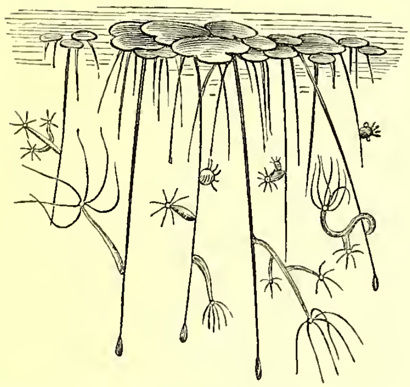
The Hydræ are to be met with abundantly in summer time in almost every pond or ditch, and may easily be collected along with the duck-weed or other aquatic plants among which they reside. On filling a glass jar with the water in which they reside, and allowing it to stand for a few hours undisturbed, the little polypes will be found, sometimes in great numbers, adhering to the sides of the vessel, in which position nothing is easier than to watch their proceedings, and with the assistance of a simple magnifier to verify the descriptions which Trembley and others have given of the extraordinary phenomena they exhibit.

The *Hydra viridis*, or short-armed polype, which is the species most commonly met with in this country, resembles, when expanded, a little bit of green sewing-silk, about the sixth part of an inch in length, attached by one extremity to the interior of the jar, or to any other fixed body, and having the opposite end slightly untwisted.

When moderately magnified, the body of the animal is found to be a little bag open at one extremity, the opening, which is in fact its mouth, being surrounded with seven delicate filamentary tentacula; while the other end is provided with a little flattened disc or sucker, by which it fixes itself to any foreign body (*fig.* 25). Its substance seems to be entirely composed of a gelatinous material, in which are contained numerous greenish granular particles suspended in a glairy

fluid; and, to an ordinary observer, no fibres of any kind are distinguishable in any part of

Fig. 25.



Hydræ virides in different stages of extension and contraction, reproducing gemmiparously, attached to the roots of duck-weed. (*From Roesel.*)

its body: nevertheless it is highly contractile, shrinking, when disturbed, into an almost invisible jelly-like speck, and again slowly expanding itself when left quiet. Incapable as such a creature would appear to be of any active exertion, this little gelatinous bag is soon found to be gifted with a capability of locomotion, which is exercised in the following manner: whilst attached to the side of the glass by the sucker at its closed extremity, which forms a minute foot, something like that of a Gasteropod Mollusk, the little polype gradually inflects its body until some of the tentacula around its mouth are brought in contact with the supporting surface, of which they take a firm hold; in this position it detaches its posterior sucker, and, advancing it towards its head, again fixes it, and thus progresses, after the manner of a leech, by a repetition of the same manœuvres. It may, however, be easily imagined that, owing to the minute size of the Hydra, and the extreme slowness of its contraction, this mode of progression is by no means remarkable for its speed, and in fact a march of an inch will occupy it many hours in its performance; accordingly the polype has been endowed with another mode of transit, of which it can avail itself at pleasure. Although its body is specifically heavier than water, so that when detached from its hold it sinks helplessly to the bottom, it is able, when occasion requires, to row itself about in a very ingenious manner. In order to accomplish this feat, it first creeps to the top of the water, and protruding its sucker to a little distance above the surface, hollows it out into a saucer-like cavity, the buoyancy of which is sufficient to keep it afloat; and then, supported by this curiously-contrived boat, the little Hydra rows itself about by means of its tentacula in whatever direction it chooses. No traces of nervous matter are perceptible in the composition of the Hydra, which, in its whole structure, is completely acrite; nevertheless it is evidently able to appreciate the presence or absence of light; for if a number of these little animals are confined in a glass vessel, one side of which is exposed to light while the other is kept in the shade, they are always found to congregate on the illuminated side, and by turning the glass round it will be found that by changing their position, they will endeavour to regain a situation exposed to the solar influences: seeing, therefore, that they are absolutely destitute of eyes, it would seem that they perceive light by the sense of touch alone.

It might naturally be supposed that a creature so low in the scale of organization would be compelled to subsist upon the simplest possible aliment, yet, strange to say, this little polype is carnivorous in its propensities, and is moreover gifted with such terrible powers of destruction, that animals far larger, stronger, and more active than itself fall a prey to its voracity: the Entomostracous Crustaceans, the larvæ of insects, and minute Annelidans, constitute its ordinary diet, and vainly endeavour to escape from its clutches. Whilst watching for prey, the Hydra remains perfectly at rest, suspended by its tail, and keeping its oral tentacula widely spread out in different directions, nor has it generally to wait long before some of the multitudinous animals that crowd the water in its vicinity impinge against its outspread lines, when immediately, as if the wand of an enchanter had been laid upon it, the career of its victim is arrested; though apparently only touched, not seized, it immediately sinks motionless as though paralysed by the contact, and only after some time recovers its former vivacity. What is the benumbing power possessed by the tentacula of the Hydra it is difficult to conjecture; some writers attribute it to a torpifying secretion; others surmise the discharge of an electric shock; but whatever be its nature, its effects are sufficiently potent to prevent the escape of the animal subjected to its influences.

No sooner is the prey thus stricken motionless than the tentacle against which it impinged begins slowly to contract and drag it towards the orifice of the mouth. It would seem that the slightest effort on the part of the animal seized would be sufficient to tear off the almost invisible gelatinous arm of the polype, yet not more surely does the angler land a trout by means of his silken line, than the Hydra succeeds by its tenacious hold in securing its victim; tentacle after tentacle is brought to bear upon it, and slowly it is approximated to the opening of the stomach of the polype in which it is about to be engulphed.

When lodged in the stomach of its devourer, so thin and diaphanous is the distended bag of the Hydra's body, that the animal swallowed is still distinctly visible, and the microscopical observer would scarcely suspect that the pellucid film which covers it was capab'e of producing much effect upon its substance. Gradually, however, the swallowed prey begins

to lose its distinctness of outline, and its parts become dim and confused, for the process of digestion has begun, and speedily all that is digestible is dissolved, nothing being left but the hard shell and other intractable portions, which are at length expelled from the digestive sac through the same opening by which they were admitted.

From the transparency of the Hydra, Trembley thought to be able to ascertain the manner in which the digested nutriment became appropriated, and observing that the polypes became coloured in accordance with the kind of food upon which they lived, proceeded to feed them with the red larvæ of certain insects, in hopes of seeing how the colouring matter became diffused through their bodies, and in this he was partially successful ; the result of his experiments proving that it was through the medium of the granules floating in the semifluid transparent substance of the Hydra that the diffusion of the coloured particles was accomplished, the granules themselves assuming the tint of the coloured food, while the gelatinous matter in which they were suspended remained colourless.

Another remarkable fact observed by Trembley was, that the digestive powers of the Hydra had no influence over the tissues of its own body, for frequently he observed that the long-armed species swallowed their own tentacula along with their food, the former remaining quite intact while the latter was in process of solution, and on one occasion when two Hydræ had both of them seized on the same prey, and were contending for the possession of it, one of them decided the contest by swallowing the subject of dispute and his rival into the bargain. Naturally supposing that the death of the swallowed polype would be the result of such an apparently tragical termination to the dispute, Trembley was not a little surprised to see the successful polype disgorge his antagonist safe and uninjured along with the egestamenta of the meal, and to all appearance none the worse for its temporary incarceration.

If a Hydra be divided transversely, by means of a knife or a pair of scissors, both halves not only survive, but in the course of a short time each moiety reproduces the portion of which it has been deprived, the hinder extremity developing a new set of tentacula, and the anterior portion acquiring a sucker to replace that which was lost ; nay, it has been proved that even when divided into several fragments, each piece retains its vitality, and in process of time regains all the characters of a perfect individual, just as the cutting of a plant speedily puts forth roots and leaves similar to those of the original stock from which it was taken.

Not less wonderful than their capability of recovering lost parts after mutilation are the powers which they possess of multiplying their species by various modes of generation. The most usual manner in which they produce offspring is by gemmation, the nature of which, owing to the transparency of their bodies, they are admirably adapted to elucidate. The process by which this kind of reproduction is effected in the case of the Hydra is as follows. After keeping one of these polypes for a few hours well provided with food, a little bud or *gemma* is seen to sprout from some portion of the surface of its body, which at first seems to be a shapeless excrescence, but in the course of a short time assumes the shape of the parent animal by developing tentacula from around the oral orifice, which gradually becomes more and more distinct. For some time the newly formed polype remains attached by the little pedicle at its tail to the body of its parent, with which it seems to enjoy a sort of community of existence, the food caught and digested by the one passing freely through a little aperture in the caudal extremity of the young polype from one to the other. At last, when the growth of the off-sprout is completed, it detaches itself, and assumes an independent existence ; yet sometimes even before its separation is accomplished the bud of a third generation may be observed appended to the side of its body ready to undergo the same process of development.

The formation of the reproductive gemmæ may even be determined by extraneous causes: thus Trembley noticed that by snipping the side of an adult polype with the points of a fine pair of scissors, a bud would soon develope itself from the wounded part; and this experiment might be repeated again and again, both upon the original polype and the progeny thus made to sprout from its sides, until as many as seventeen have been obtained, all connected with each other, and thus forming a little tree of living polypes.

Besides the gemmiparous mode of reproduction, Hydræ have been occasionally observed to divide themselves spontaneously by transverse fissure, and thus separate into two animals, in the same way as some of the Polygastric animalcules.

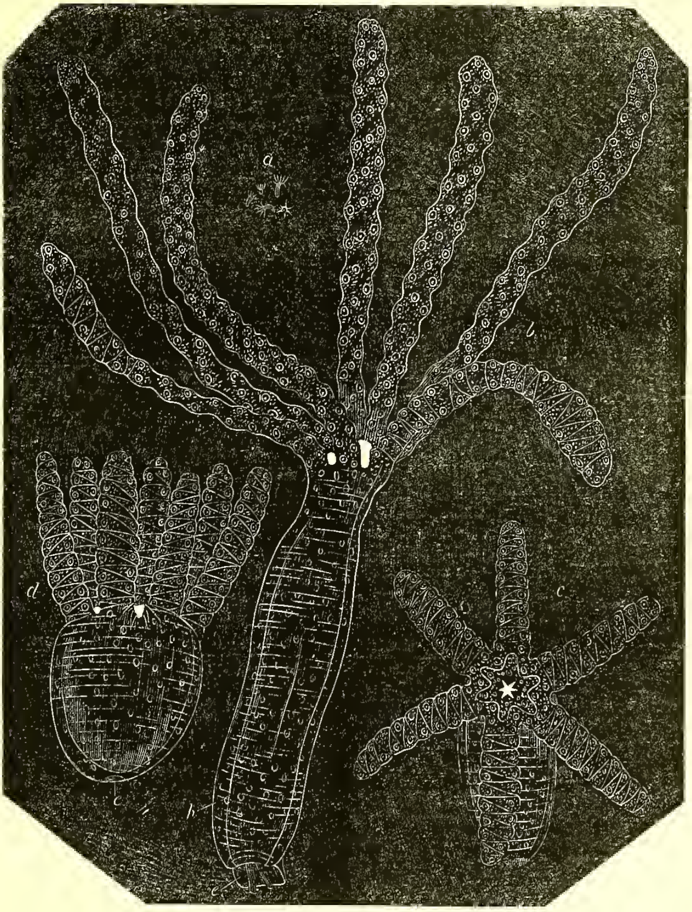
The anatomy of the Hydra has been recently closely investigated by Corda, whose observations upon this subject are possessed of extreme interest.* According to this observer each tentacule of the Hydra consists essentially of a long, pellucid, and extremely delicate membranous tube (*fig.* 27) containing an almost fluid albuminous substance, which in certain definite localities swells into denser wart-like knots (*b*), arranged in a spiral line, along which are appended organs of touch (*d*), and also instruments of prehension (*c*). Situated within the tube, and running immediately beneath the above-mentioned nodosities, which are arranged in a quaternian series, are situated four longitudinal bands of muscular fibres of a slightly yellow colour (*e*), which seem to be the *extensors* of the tentacles.

These *extensors of the tentacula* are moreover united to each other by transverse muscular fasciculi (*f*) of the same colour as themselves, which Corda names *adductors* of the

* Anatome Hydræ fuscæ exposuit Augustus Josephus Corda, cum tabulis tribus. Acta acad. Cæs. Leopold. Carol. naturæ curiosorum, vol. xviii.

tentacles, as he considers that when fully extended the tentacle is by their action folded up like a fan. The observations of the same writer lead him to consider that there is no

Fig. 26.



Hydra fusca. (*After Corda.*)

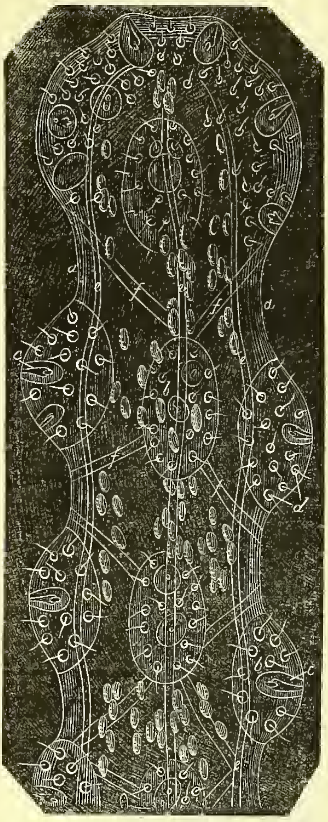
a, natural size; *b*, magnified, extended; *c*, magnified, contracted, viewed vertically, so that the mouth is seen; *d*, magnified, contracted; *e*, foot.

communication whatever between the interior of the tentacula and the cavity of the body, for the tentacle is filled up with the albuminous material in which are dispersed brown coloured granules, apparently of an oily nature.

In the wart-like nodosities which wind in a spiral course round the tentacula, Corda finds what he considers to be organs of touch (*fig.* 27, *d*, and *fig.* 28, 1, 2). Each of these consists of a delicate sacculus implanted in the wart-like excrescence (*fig.* 28, *p*), which encloses another (*q*), provided with thicker walls and containing in its interior a minute cavity (*r*). Every one of the singular bodies thus organized supports an almost imperceptible filament (*s*), completing the supposed tactile apparatus.

In the midst of every group of these filament-supporting vesicles was found an instrument adapted to seize prey, which its discoverer names a dart (*hasta*). This apparatus consists of a transparent oval sac (*fig.* 28, *l*), imbedded in the substance of the tentacle (*k*), and furnished above with a small orifice (*h*). At the bottom of the sac is situated a saucer-shaped body (*m*), upon which is placed a solid oval corpuscle (*n*), and this again supports a long and sharp spiculum (*sagitta*), composed of calcareous matter (*o*), capable of protrusion and retraction through the aperture *h*, apparently by the eversion and retroversion of the saucer-shaped bladder to which the oval basis of the dart, *n* (*hastifer*), is appended. Whenever the Hydra would seize any animal, the darts of the tentacle become extruded, and its whole surface is thus rendered tenacious. Yet this does not seem to be all; it would appear that

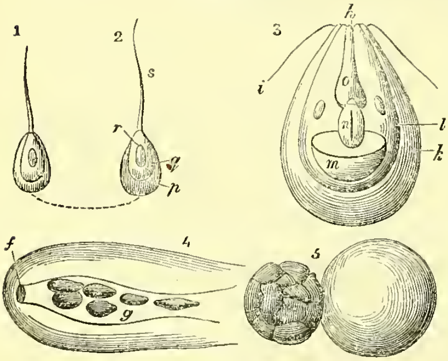
Fig. 27.



Hydra fusca — end of a tentacle extended, magnified.

a, investing membrane; *b*, nodosities; *c*, prehensile darts; *d*, tactile cilia; *e*, longitudinal, and *f*, transverse muscular fasciculi. (*After Corda.*)

Fig. 28.



Hydra fusca.

1, 2. Tactile cilia and their sacculi highly magnified; *p*, first sac; *q*, second sac; *r*, minute cavity; *s*, cilium.

3. Prehensile apparatus highly magnified; *h*, aperture; *i*, epidermis of the tentacle; *k*, first sac; *l*, second sac; *m*, saucer-like body (vesica); *n*, oval basis (hastifer); *o*, dart.

4. Intestinal villus highly magnified; *f*, foramen; *g*, cavity of the villus.

5. Particles of fat or oil. (*After Corda.*)

the sagittæ are empoisoned, as an animal once laid hold of by the Hydra very speedily dies.

At the base of the tentacula, the opening of the mouth is surrounded with lips capable both of inflection and protrusion. This lip is similar in structure to the tentacles themselves, and is in like manner provided with tactile appendages, and with prehensile sagittæ upon its external surface. These lips, by their contraction, shut and open the mouth at the pleasure of the Hydra, and, when the size of the animal is taken into the account, appear to be endowed with extraordinary muscular force. The rest of the body is quite devoid both of sagittæ and of tactile organs.

The body of the Hydra, according to Corda, is covered externally with a membrane that consists of two layers, of which the exterior (*fig.* 29, *a*) is composed of large cells, whilst in the inner layer are contained the *germina*, of which we shall immediately have to make further mention.

Between the skin and the alimentary canal Corda announces the existence of a muscular layer (*fig.* 29, *b*), composed of dense cells, which are coloured, and appear to be filled with minute granules.

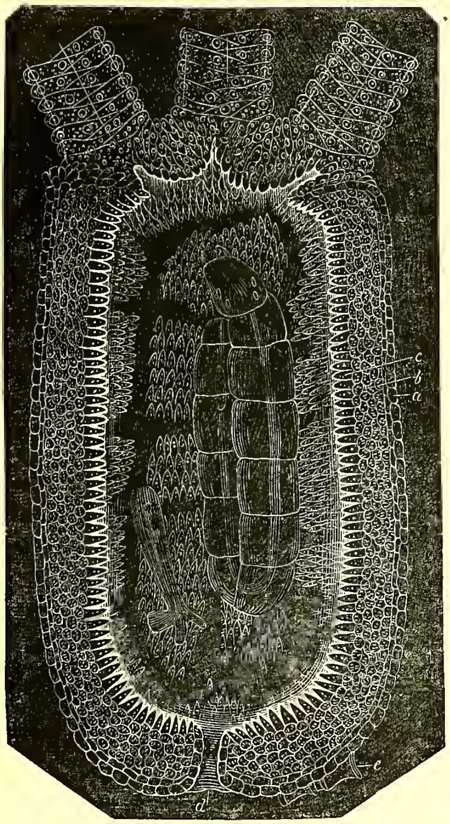
The innermost layer of all (*fig.* 29, *c*), from its position and texture, ought, according to the same author, to be called the villous coat (*tunica villosa*). This stratum lines the entire alimentary tract, from the margin of the labial processes as far as the anus, being divided at intervals by folds into numerous compartments. The villi of which this stratum consist are intimately connected with the muscular layer; their shape is cylindrical, but they are of two kinds, some being perforated at their apex by a foramen, whilst the others are close. Each of these villi (*fig.* 28, 4) is a rounded, pellucid vesicle, the walls of which are thick, and probably contractile, and in those which are perforated the perforation would seem to convey nutritive matter into their interior.

Behind the anal orifice there is a small, hollow, and contractile membranous prolongation (*fig.* 29, *e*), which constitutes the sucker, or foot.

ANTHOZOA.

Alcyonidæ. — The races of polypiferous zoophytes which next offer themselves for our examination may be described as consisting of a common body or central mass, over the surface of which are disseminated numerous polypes, all of which contribute to the nutrition of the community to which they belong. In the first family, *Alcyonium*, examples of which are abundant on our own shores, the substance of the polypary or general body, which may frequently be picked up upon the beach, appears to be a shapeless lump of a tough gelatinous substance, upon which, to an ordinary observer, no indications of its wonderful organization are apparent; so that we cannot wonder at its being so frequently passed by as an object devoid of interest. On putting one of these amorphous masses into a glass of sea-

Fig. 29.



Hydra fusca, containing the larva of an insect partially digested.

a, large superficial cells of the integument; *b*, muscular stratum, the cells of which are very minute, granular, and coloured; *c*, villous tunic; *d*, anus; *e*, hollow membranous prolongation or foot. (*After Corda.*)

water, however, and allowing it to remain for a little time undisturbed, its real nature becomes apparent and a series of most interesting phenomena present themselves. The mass, which was at first opaque and of a dense texture, slowly swells and becomes more diaphanous, apparently by the absorption of the surrounding water into its substance, until, having attained its full dimensions, numerous dimples appear, studding its entire surface, each of which, as it gradually expands, reveals itself to be a cell, the residence of a polype, which, emerging from its abode, displays eight pinnated arms, and the entire Alcyon, thus studded with living flowers, presents a spectacle of extraordinary beauty, but if disturbed speedily withdraws from observation and again shrinks into its former shapeless condition.

M. Milne Edwards* has thrown considerable light upon the organization of these beautiful structures by his indefatigable researches, the results of which we shall lay before the reader at some length, as they are of great importance in illustrating the economy of the polypiferous zoophytes.

The genus *Alcyonide* (*fig.* 30) has the polypes grouped together in great numbers upon the surface of a soft cylindrical polypary or common body, which consists of two portions. The lower portion (*b*), which is attached by its base to fuci or other submarine substance, is of a brown colour and firm texture, whilst the upper part is white, membranous, and extremely delicate, divided into branches the summits of which are crowned with elegant polypes (*d*) of almost microscopic dimensions. Each of these polypes has eight pinnated tentacles, in the centre of which is the opening of the mouth.

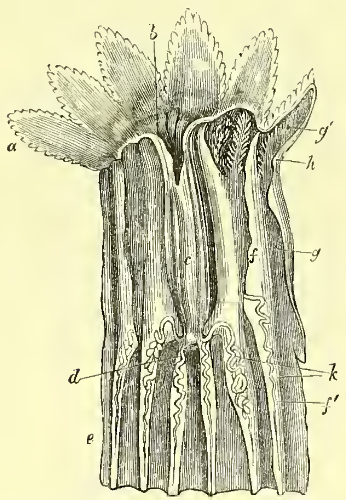
Fig. 30.

A group of Alcyonides (*Alcyonidium elegans*) fixed to a marine plant, of the natural size. On two of the great divisions of the polypary the animals are completely developed, whilst in the third (*e*) the whole of the soft portion of the polypary is contracted and withdrawn within the basilar portion. *a*, branch to which the polypary is fixed; *b*, foot or basilar portion of the polypary; *c*, trunk or membranous portion; *d*, polype-bearing branches; *f*, yellowish spots occasioned by the presence of ovules in the inferior portion of the trunk. (*After Milne Edwards.*)

* Ann. des Sc. Nat. tom. iv. 1835.

On observing these zoophytes in the living state, each polype is seen to be capable of executing individual movements ; sometimes they expand their tentacles, or bend them inwards towards their mouth, or retract them into the interior of their bodies, or retreat entirely into the substance of the common polypary, as into a cell, without the neighbouring polypes at all changing their position. In this respect each polype is independent of the surrounding ones. Under other circumstances, however, this is not the case, for sometimes the common body of the creature evinces movements that influence all the polypes, and cause their simultaneous contraction ; and this contraction is occasionally continued to such a degree that all the soft upper portion shrinks into the coriaceous stem, so as to become imperceptible, as represented in the figure (*fig.* 30, *e*). On separating one of the polypes

Fig. 31.



Alcyonidium elegans. Upper portion of one of the polypes magnified, and opened longitudinally.

a, tentacles; *b*, mouth; *c*, stomach; *d*, inferior aperture of the stomach; *e*, upper part of the abdominal cavity; *f*, membranous partitions extending from the stomach to the walls of the cavity in which it is suspended (some of these are cut in the section, others are in place); *f′*, longitudinal folds of the abdominal parietes continuous with these partitions; *g*, the canals that surround the stomach and terminate in the tentacles: *g′*, one of the tentacles laid open; *h*, groups of spicules situated at the base of the tentacles; *k*, filiform appendages to the stomach, probably hepatic. (*After Milne Edwards.*)

from the common mass, and opening it under a microscope in a longitudinal direction, it is found that its central portion is occupied by a cylindrical stomach (*fig.* 31, *e*) which is open at both extremities, and presents internally eight longitudinal bands and a multitude of transverse folds: inferiorly it is contracted, and looks as if its termination was surrounded by a sphincter, although no muscular fibres are perceptible. At length the inferior contracted orifice of the stomach opens into a wide cavity (*d*), which occupies the entire diameter of the polype, and is prolonged inferiorly into the substance of the polypary. The calibre of the stomach itself is much smaller than that of the body of the animal, in the centre of which it is suspended by means of eight membranous and extremely delicate septa (*f*), which pass between the outer surface of the stomach and the parietes of the polype, forming so many vertical partitions. By their upper extremity these septa are blended with the periphery of the mouth, and thus circumscribe between them eight longitudinal canals (*g*), which are continuous with the corresponding tentacles. These latter appendages are in fact entirely hollow, and present on each side of the cavity which they enclose a series of ten or a dozen little apertures opening into the pinnules along their borders.

Inferiorly, the eight interseptal compartments communicate freely with the great cavity (*d*), situated beneath the stomach, the membranous septa becoming gradually continuous, with eight longitudinal folds (*f′*) that project into its interior. Just at the point where each of the membranous septa ceases to be continuous with the walls of the stomach and becomes free by its inner margin, may be observed a filiform flexuous organ (*k*), the nature of which appears to be glandular.

The common polypary from which these polypes issue is composed, as was stated above of two distinct portions (*fig.* 30, *b*, *c*). The superior soft portion is found by dissection to be made up of an assemblage of longitudinal membranous tubes placed parallel to each other, and so closely conjoined that it is difficult to separate them, and in fact the hard base of the polypary is nothing more than a continuation of these tubes, slightly altered in their structure: those situated near the centre of the stem are only distinguishable by a slight thickening of their walls, but those near its circumference acquire a much harder consistence, their parietes being encrusted with multitudes of brown-coloured fusiform spicula, which appear to be composed of a cartilaginous substance and of carbonate of lime. These spicula are arranged in a longitudinal direction, and confer upon this part of the polypary its solidity and peculiar aspect. Near the circumference of the polypary many of the tubes seem to be obliterated by pressure of the contiguous parts. On tracing the tubular structure downwards towards the base, each tube gradually disappears, either by becoming obliterated, or by anastomosing with the surrounding ones, whilst superiorly it is found to be continuous with the abdominal parietes of a polype, the sheath of which it forms when it is in a state of contraction.

The tubes thus united into fasciculi are evidently analogous to the cavities into which the polypes of Alcyons, Corals, &c., withdraw. These cavities are generally called "polypiferous cells," and some writers consider them as being species of cases or envelopes more

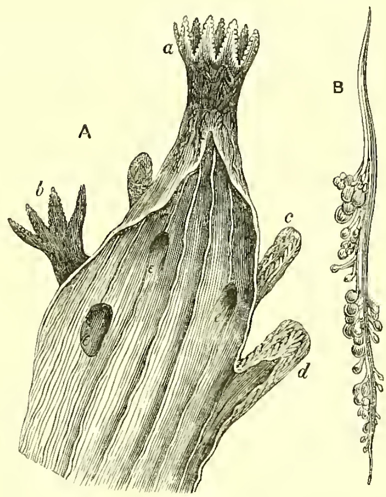
or less distinct from the animals themselves; but in the Zoophyte we are speaking of a superficial examination is sufficient to convince any one that these cells are in reality continuations of the bodies of the polypes themselves. The tubes which form the trunk (*fig.* 30, *c*), are in all respects similar to the free portion of the animal which is situated beneath its alimentary canal, and no line of organic separation can be traced dividing one from the other. It is not, therefore, into polypiferous cells that these little animals retire in the manner of Serpulæ or Dentalia, but they recede into themselves by a kind of invagination of their own bodies, the polypary, which seems to contain them, being simply a mass formed by an assemblage of the basal portion of all the aggregated zoophytes.

When the polypes extend themselves, their mouths may frequently be seen to open and admit the surrounding water. This fluid, together with the alimentary materials suspended in it, penetrate into the digestive sacculus, and afterwards pass into the great abdominal cavity, whence they are conveyed even into the tentacula by the eight canals placed around the alimentary tube. It thus results that the thin and diversely folded membrane, of which the bodies of these animals are formed, is everywhere bathed, both within and without, with the materials for respiration, and that all its internal surface receives the contact of the alimentary substances after their elaboration in the digestive sacculus. M. Milne Edwards likewise thought he perceived something like a circulation in canals contained in the parietes of the body; but of this he was uncertain.

Nutrition of Alcyonidæ. — It is very generally admitted that in the case of these aggregated zoophytes the nutritious materials taken by one of the animals is shared with the neighbouring polypes; and this fact M. Milne Edwards has established beyond the possibility of doubt, as well as the manner in which it is effected. In an expanded *Alcyonide* he introduced, by means of a fine pointed glass tube, a coloured fluid into the abdominal cavity of one of the polypes, and immediately the injected material diffused itself, not only throughout the tubiform body of the individual so treated, but passed at the same time into the neighbouring polypes. The passages by which this communication is established are easy to discover, by making a longitudinal section of the body of the Alcyonide. It is then seen that some of these animals, whose tube-like bodies are prolonged deeply into the common mass, there terminate by *culs de sacs*, whilst others are not continued beyond the point where they join their congeners; and in this case their bodies are found to be continuous with that of a larger polype, the basal portion of which descends lower down (*fig.* 32). The abdominal cavities of these animals are thus united, so as to constitute a kind of branched tube, possessed of as many heads and mouths as there are polypes derived from it.

This condition of their nutritive system arises from the mode of their development by

Fig. 32.



Alcyonidium elegans.

A, one of the branches laid open to show the communication between the abdominal cavity of the principal polype and the interior of the young ones that spring from it; the openings thus formed, (*e, e, e,*) are situated in the course of the longitudinal folds, which perform the office of ovaries. *a*, tentacles of the principal polype; *b, c, d*, the young polypes in progressive stages of development.

B, the lower portion of one of the longitudinal folds detached, showing the manner in which the ova are developed in it. (*After Milne Edwards.*)

gemmiparous reproduction, which takes place as follows. A tubercle makes its appearance upon the surface of the body of an adult polype, which seems at first to be only a little cœcal appendage developed from its parietes, its extremity being without any opening and the cavity in its interior communicating freely with the abdominal cavity of the individual from which it was developed. Shortly, however, as its development proceeds, a mouth and its surrounding tentacula make their appearance, an alimentary cavity becomes apparent, and the newly formed animal becomes, both in shape and size, exactly like the individual from which it sprouted.

This mode of reproduction, Milne Edwards remarks, does not occur at any point of the tegumentary surface. The reproductive gemmæ are only formed along the course of the membranous lamellæ already mentioned, and the inferior opening of the body of the new polype is always so situated as to intercept one of the longitudinal folds in the abdominal cavity of the parent animal.

But the mode of reproduction by gemmæ is not the only one by which the Alcyonides are multiplied. They produce also ova, or gemmules, by means of which their sedentary race may be disseminated; and it is remarkable that the same parts which give birth to the gemmæ above described perform likewise

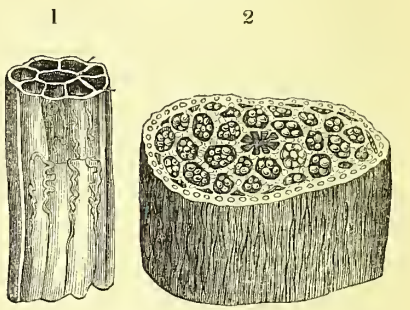
the office of ovaries. The ova are, in fact, developed in the substance of the longitudinal membranous folds from which the gemmæ sprout. As they grow larger they project internally, and soon become pedunculated; at last, when mature, they detach themselves from the ovigerous fold and fall into the abdominal cavity, whence an issue is afforded to them through the mouth of the polype. No ovule is ever developed from the parietes of the abdominal cavity intervening between the longitudinal folds; and hence there can be but little doubt that these lamellæ represent the ovaria of the animal.

On seeing the same organ producing sometimes buds, or *gemmæ*, and sometimes ova, Milne Edwards was led to inquire into the cause of this difference in the mode of reproduction, which he conceives to be of a mechanical nature. In those parts of the polype which are not yet imprisoned in the growing mass of the polypary, reproduction is generally effected by the development of external buds, while towards the base of the polypary, where the constituent zoophytes are intimately united together by their outer surface and are surrounded by a sort of sheath, no external buds are formed, but the ovules make their escape into the internal cavity of their parent. Hence the distinguished zoologist, whose memoir we quote, is led to infer that, on the one hand, the mechanical obstacles to be encountered, and on the other the excitement occasioned by the contact of the surrounding element, determine this difference of procedure, and that the membrane which performs the functions of an ovary produces indifferently either ova or gemmæ, according as it finds less resistance or is more stimulated on the inside or the outside of the abdominal walls.

From the above details it becomes easy to explain how a single polype, by its reproductive powers, can form the complicated mass of the compound polypary of the Alcyonide, as well as the means whereby an organic continuity is established between all the individuals of the community; also how the abdominal cavity of the primitive individual becomes common to all the young ones that sprout from it; in short, how the little beings, thus united together, rather resemble a single multiple animal than an assemblage of distinct individuals. But with the advance of age this intimate union gradually diminishes. The communication between the abdominal cavities of the different polypes whose basal portions reach as far as the foot of the polypary is first of all interrupted by the ova, with which the lower part of these cavities becomes filled (*fig.* 33, *f*); and subsequently, by the pressure of the surrounding parts, the walls become confused, and all communication between the polype whose abdominal tube is thus obliterated and the polype from which it sprung is intercepted.

The polypary, instead of resembling a tree, all the flowers of which hold together and communicate by common parts, may now be compared to a *bouquet* made by cutting off the more or less branched twigs of a plant

Fig. 33.



Alcyonidium elegans.

1, transverse section of the body of one of the polypes, to show the manner in which the eight longitudinal folds are attached around the alimentary canal, forming as many longitudinal canals that extend from the abdominal cavity into the extremities of the tentacles.

2, transverse section of the basilar portion of the polypary, showing the continuation of the abdominal cavities of the polypes with their longitudinal folds, and the germs filling them.

and collecting them in a bundle. The different groups of polypes united in the same polypary become thus independent of the neighbouring groups, and, as may readily be conceived, in time each polype can become individualized.*

The filiform organs (*fig.* 41, *k*), situated below the digestive cavity, are evidently not ovaria, as they have been considered to be by many authors, seeing that the ova are formed elsewhere; neither does M. Milne Edwards consider that they can be seminiferous organs, but is inclined to regard them as hepatic vessels.

In the genus *Alcyonium* the zoophyte is composed of two principal portions. The common central mass is of a coriaceous texture, porous, and somewhat like cork, being formed of a dense substance, which, when cut into pieces, feels gritty under the knife, owing to the quantity of earthy spicula diffused through its mass. Externally it consists of a reddish granular substance, in which the polype cells are excavated, but internally it is of a grey colour, and permeated by numerous tubes that descend towards the base of the zoophyte, and frequently run into each other. These canals are filled with a gelatinous fluid, and lined with a red material prolonged from the external layer.

The polypes which stud the surface are as fine as hairs; but still, with the aid of the microscope, it is not difficult to distinguish the mouth, the vesicular stomach, the muscular envelope of the animal, the ovary, and the glandular organs which depend from the base of the stomach into the abdominal cavity of the polype. Its whole structure has been

* Raspail, Polypes d'eaux douces.

well described by Spix, and subsequently more in detail by Milne Edwards in the paper above referred to. The following is the result of Spix's observations.

"The mouth is a small rounded aperture, which is very dilatable, and communicates immediately with the stomach. The mouth is surrounded by eight tentacles, having a papillary surface, and they appear to contain internally a multitude of little air bubbles. They are very sensible, for as soon as they are touched they retract, and the animal retires into its cell.

"The polype is retained in its domicile by a muscular membrane, which is very distinct from the walls of the stomach, and is almost cylindrical; it descends from around the mouth, and is fixed to the edges of the cell; it appears to form the tentacles and the stomach, as in Actinia. The contraction and extension of the polype is effected by this membrane."

For many days during which Spix watched these polypes he observed little globular bodies to ascend from beneath the stomach and issue at the mouth. By pressing gently he saw them glide as by a little orifice into the stomach, and by the same proceeding he succeeded in pushing them under it.

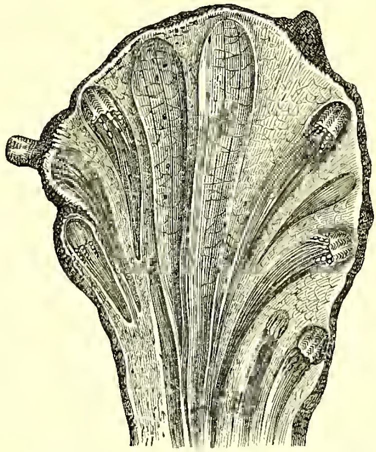
Having raised the muscular membrane at the point where it is fixed to the polype, he perceived at the bottom of the cell, and beneath the stomach, seven or eight globules contained in a bent canal (*ovary*), placed in a row. They gave to the canal the appearance of a row of vesicles. The globules are round; those which are most developed red, each enclosing a multitude of ova.

"When the animal is drawn out of its shell, by tearing the muscular membrane, the ovary detaches itself from the stomach and remains at the bottom of the cell. But there is another grey body like a tail, which follows the stomach, and is attached to it opposite to the ovary. This body is round, very thin, and so slender that it does not fill the tube in which it is placed; it is therefore difficult to imagine that it descends to the base of the zoophyte to unite with the rest."

The above account, it will be perceived, agrees very closely, as far as it goes, with Milne Edwards's description of the anatomy of the Alcyonidium; but the last mentioned naturalist has prosecuted the investigation of these zoophytes still more minutely.

In the Alcyons, properly so called, the vascular system is very distinctly developed, and in *Alcyonium stellatum*, more especially, M. Milne Edwards was able to study it with facility. In this species he was enabled to detect upon the parietes of the abdominal cavity of the polype a variable number of minute apertures irregularly dispersed, which are in immediate communication with a system of capillary canals that traverses in all directions the spongy portion of the polypary formed by the external tunic of its component animals. For in this species it is very easily seen that while the internal tunic lines the abdominal cavity of the polype, the external layer, instead of being confounded with the former, as in

Fig. 34.



Alcyonium stellatum. A portion of the polypary divided longitudinally, showing the ramifications of the vascular system in the spongy substance separating the abdominal cavity of the polypes; on the parietes of these cavities the mouths of many of the vessels are seen. (*After Milne Edwards.*)

the protractile portion of the animal, becomes perfectly distinct from it at the point where it begins to enter into the composition of the polypary, at which its thickness becomes considerably augmented, its texture spungoid, and in its substance are deposited a number of irregular crystals, composed of carbonate of lime mixed with a little colouring matter. In the tegumentary mass thus formed, the vascular canals ramify, anastomosing freely among themselves, so as to constitute a vascular network. These vessels are formed of very attenuated membrane of a yellowish colour, which is continuous with the internal tunic of the polypes, and is perfectly distinguishable from the dense tissue with which it is surrounded. The distribution of these canals is best displayed by cutting a thin slice of the mass of the Alcyon and removing the crystals with which it is filled by immersion in some dilute acid; it is then seen that the canals are most numerous and of the largest size towards the extremities of the branches of the polypary, and that they establish frequent communications between the abdominal cavities of the different polypes. This organization evidently establishes a very intimate connection between the different polypes of the Alcyon. The fluids with which their bodies are filled must thus necessarily circulate in the entire mass of the polypary, and if each of the polypes has, on the one hand, an individual sensibility, and a distinct digestive cavity on the other, there is a vascular system common to them all.

The *Alcyons*, like the *Alcyonidæ*, are reproduced by ova, which are formed in membranous ovaria of precisely similar construction, and also by gemmæ, which in the Alcyon are

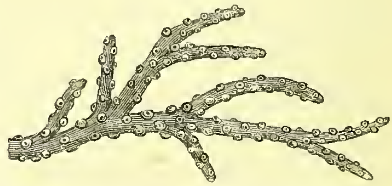
developed around the pre-existent polypes, and thus augment indefinitely the number of individuals united upon one stock. There is, however, a very important difference observable between these two genera of zoophytes, in other respects so similar. In the Alcyons the abdominal cavity of the young polypes is not directly continuous with the abdominal cavity of their parent, and it is only by the intermedium of the vascular system described above that they are placed in communication with each other; a modification which depends upon another difference in the mode of formation of the reproductive gemmæ. When an Alcyon stock is about to put forth a new branch, the spongy part of the polypary (that portion which is formed by the external tunic of the polypes and permeated by the vascular network) begins to increase in size at some determinate point of its periphery, and soon produces a tubercle of greater or smaller size, into which the vessels spoken of above are continued, and form numerous anastomoses with each other. At this early period of development the new branch presents no trace of polypes, but its vascular tissue is nevertheless already studded with calcareous crystals, and exactly resembles that situated in other parts of the common mass between the abdominal cavities of the adult polypes. It must, therefore, necessarily be traversed by the currents which circulate in the general vascular system. On dissecting one of these newly formed branches the vestiges of young polypes may be distinguished; and if the sprouts examined are still further advanced, it is easy to distinguish the young animals within, already possessing the form they will afterwards exhibit, but which have not yet established a communication with the exterior. At length, however, this communication is established, and the newly formed polype only differs from the pre-existing ones in its small size, and as it grows its increase causes the enlargement of the polypary of which it forms a part. In this case it is very evident that the part which gives birth to the reproductive gemmæ is no portion of the individual polypes of the Alcyon, but is common to them all. The generative tissue surrounds these little beings with a sort of living sheath, and produces in the interior of its own substance new polypes, quite independently of those previously in existence. These polyparies might therefore be compared to a sort of common ovary, the products of which are never completely individualised, but remain permanently lodged in its substance, and minister to the support of its existence and the aggrandizement of its tissue.

This singular mode of reproduction, M. Milne Edwards observes, seems at first sight to be very different from that observed in the *Alcyonidium;* but, on reflection, a considerable analogy may be traced between them. In *Alcyonidium* the internal tunic of the abdominal cavity fulfils the functions of an ovary, and produces at determinate points both gemmæ and ova; whilst in Alcyon, on the contrary, while the internal membranous layer gives birth to ova, the gemmæ are developed elsewhere, from the canals which permeate the common mass. But the membrane which forms these canals, and which is the seat of this kind of vegetative reproduction, is merely a continuation of the internal tunic; and hence it is easy to understand how it may fulfil analogous functions.

Corallidæ.—The *cortical polypes*, as they have been named by authors, mainly differ from the Alcyonidæ from the circumstance that the fleshy cortex which constitutes the common polypary, instead of being merely indurated by the deposition of earthy spicula in its interior, secretes for itself a solid central axis, upon the ramifications of which it is spread out, and thus enabled to form itself into arborescent expansions, of dimensions such as would be quite unattainable without this arrangement. The composition of this central axis varies in different genera; sometimes it is dense and stony (*Lithophyta*); sometimes flexible, and composed of a horny substance (*Keratophyta*); this difference is, however, of no physiological importance, for very frequently the two substances are secreted in the same individual in different portions of its substance. The solid element in the Lithophyta is carbonate of lime; in the Keratophyta it is concrete albumen.

"A species of Gorgonia, of a black colour and high polish, like black sealing-wax (*Anti-*

Fig. 35.



Branch of Gorgonia Umbraculum slightly magnified.

pathes?), examined by Mr. Hatchett*, was found, by immersion in dilute nitric acid during 28 days, gradually to become transparent and of a bright brownish yellow. In this softened state it was steeped two days in water, and was then opened longitudinally; by this the whole structure became apparent, and consisted of thin coats or tubes of a beautiful transparent membrane, which beginning from a central point gradually became larger, according to the order in which they receded from the centre. These membranes were so delicate that the fibrous texture could scarcely be discerned.

The acid in which these had been steeped was tinged of a very pale yellow. Ammonia being added changed it to a deep yellow or orange colour; but the transparency of the liquor was not disturbed by this or any other precipitants which had been employed in the former experiments.

* Phil. Trans. 1800.

Fig. 36.

Gorgonia nobilis. *A small detached portion magnified.*

When this Gorgonia was exposed to a red heat, it crackled and emitted a thick smoke, with the smell of burnt horn. The shape was soon destroyed, and a compact coal remained. By continuing the red heat, a very small portion of white matter was obtained, which, as far as the quantity would allow, proved to be muriate of soda with some carbonate of the same.

The results of the experiments on certain Gorgoniæ, such as Ceratophyla, Flabellum suberosa, pectinata, and setosa, were not a little remarkable; for when the two portions which compose these Gorgoniæ, viz. the horny stem and the cortical substance with which it is coated, were examined separately, it was proved, —

1st, That the *stems* of these Gorgoniæ consist of a substance analogous to horn, and that the horny matter contains a quantity of the phosphate of lime, but scarcely any of the carbonate.

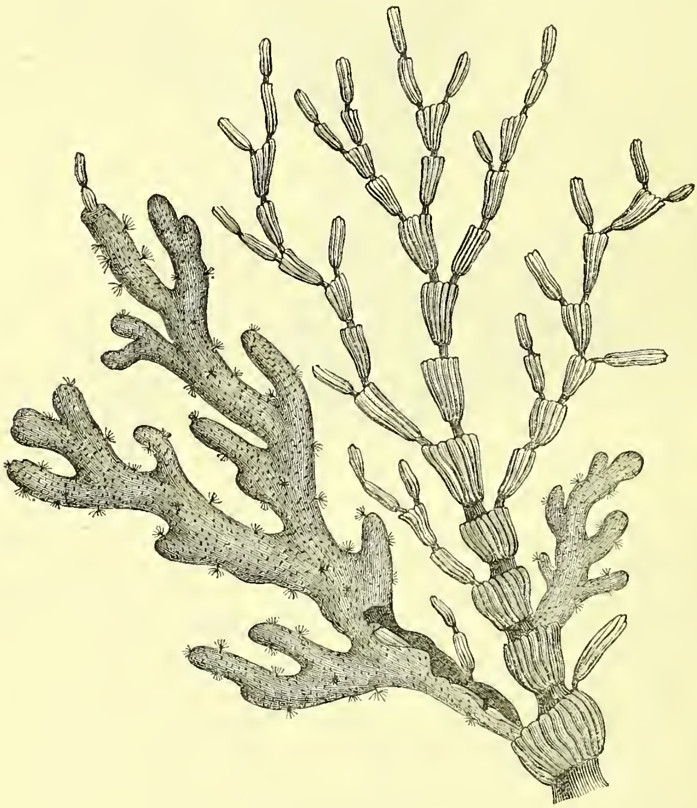
2d, That the cortical part consists principally of the carbonate of lime, with very little or none of the phosphate; and the carbonate is deposited in and upon a soft flexible membranaceous substance, which seems much to approach the nature of cuticle.

The coral of commerce, *Corallium rubrum*, is, perhaps, one of the most interesting examples of this division of Polypiferous zoophytes. In its living state this animal resembles a short stunted tree fixed to the surface of the rock by a broadly expanded base, from which it rises, at first with a single stem of varying magnitude, which soon divides into branches so as to resemble a leafless shrub rising to the height of about 18 inches. The central axis of the coral is of stony hardness, insomuch, indeed, that to this circumstance it owes its principal value in commerce, on account of the high polish of which it is susceptible. In the growing coral this stony centre is entirely invested with a fleshy cortex that constitutes the living portion of the zoophyte whereby the central stem is deposited, and the whole external surface is studded at intervals with polypes, in structure exactly resembling those of the Alcyonidæ, both in the number of their arms and general structure. During the autumnal months gemmules are formed in the ovaria of these polypes, which are described as being at first white, but afterwards of a bright red colour; these detach themselves separately from the little white groups with which they were originally connected by filaments or umbilical cords. They escape thus into the body of the polype, behind its stomach, where they are seen to be perfectly

free, and change their position by means of their vibratile cilia. When the polypes are expanded, the sea-water has a free passage through the stomach to the gemmules, which receive new vigour from its influence, and they advance towards the open posterior part of the stomach, become entangled in its aperture, pass through the stomach, and escape through the mouth. They then move about, by means of their cilia, in search of a place where to fix and develope themselves.

The stony branches of the Coral are sufficiently short and strong to resist the violence of the sea, which otherwise would break so fragile a substance, but in the Gorgoniæ and Antipathes the ramifications are so long and slender, that they would inevitably be broken by the movements of the surrounding water, were it not that the nature of their central axis is materially modified. This part of their structure is therefore very considerably modified in its texture, and being composed of flexible materials is enabled to bend beneath the passing current and rise again uninjured, while in the *Isis Hippuris* (*fig.* 37) a similar result is obtained by combining the horny and calcareous

Fig. 37.



Isis Hippuris.

matter in alternate joints. In these latter polyparies, however, although their central axes are principally composed of corneous substance disposed in concentric layers, the living cortex itself is full of granules of a calcareous nature mixed with colouring matter that varies in different genera, and as this cortex dries in a thick layer upon the central stem when the Gorgonia is removed out of the water, the varieties of colour exhibited by these zoophytes is conspicuous even in our cabinets. Cavolini* prosecuted for two successive years, 1784 and 1785, his researches on the structure of *Gorgonia verrucosa* (Lam.), and found the anatomy of the polypes dispersed over the surface of each branch to be similar to that described above as common to the Alcyonidæ and Coral; he detected the position of the ovaria at the base of each polype, and observed that the ova were discharged through eight small oviducts that open between the bases of the eight tentacula. These ova he describes as ciliated gemmules which, on their escape, swim to and fro in the surrounding water, and asserts that he saw a portion of Gorgonia, only eight inches high, discharge ninety of these in the space of an hour from the different polypes studding its surface.

* Abhandlung ueber Pflanzen-thiere, p. 48.

Madreporidæ: Madrephyllidæ.— The next group of Polypiferous zoophytes may very properly be called *Madreporygenous*, seeing that it is by their agency that vast masses of calcareous matter are constantly in process of deposition, which by their immense accumulation not only form coral reefs and islands in tropical seas, but have powerfully contributed to modify the face of our planet. The manner in which these huge territories of newly formed land are constructed by the silent labours of these humble beings is now tolerably well understood.* In climates where the heat is intense, in enclosed and tranquil bays, the saxigenous corals are found to grow upon submarine rocks, which they encrust to a considerable depth. It is upon gentle declivities and where the sea is shallow, that the largest masses of madrepores are met with. In quiet water they spread extensively, otherwise they only construct small masses formed by species which suffer least from the agitation of the waves.

It is asserted that some reefs rise from immense depths like perpendicular walls, but, although it is true that such reefs exist, they are not formed exclusively of madreporic rock, for the madreporygenous polypes can only exist at depths where they enjoy the influences of light and air, and consequently could not possibly grow at 1000 or 1200 feet below the surface. The sea, which breaks furiously upon such reefs, would inevitably destroy them, if they alone composed the cliffs; but the fact is, that sheltered from the waves in the hollows of pre-existing rocks, they contribute to increase their bulk.

Corals found upon elevated tracts of the South Sea islands and Australia have no doubt been thrown up by volcanic agency, which raised the bottom of the sea where they were formed.

When, under the shelter of submarine rocks, polypes have raised their abodes to the surface, they remain uncovered for a little time during the lowest tide. Storms turn up from the bottoms of the shallow waters sand and mud, which become entangled and fixed in the interstices of the madrepores, so that the summit of this new island comes to remain continually above the surface, and the waves can no more destroy what they have contributed to construct; its circumference gradually enlarges, and its edges grow higher by the addition of fresh sand. According to the direction of the winds or currents it may remain long barren, but if by the action of these two causes, the germs of vegetation are brought to it from neighbouring coasts, it becomes covered with verdure, by the gradual decay of which vegetable soil accumulates, until at length it becomes fitted for the abode even of man himself.

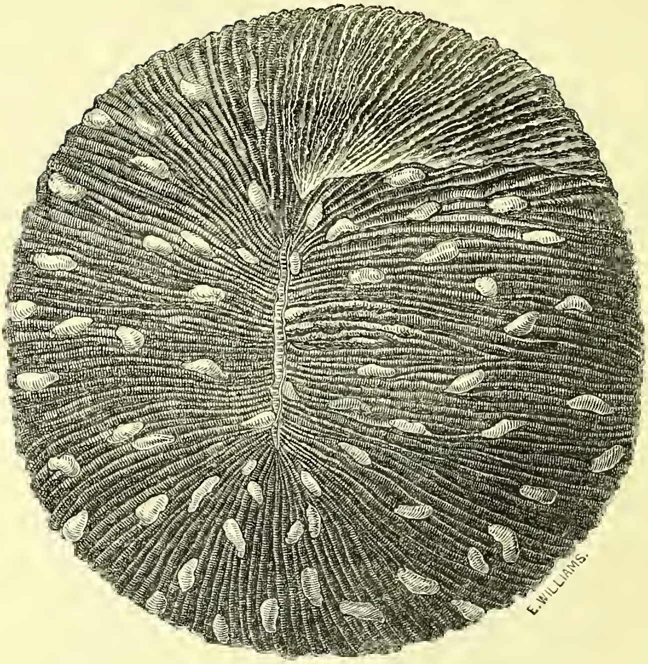
To describe all the various forms of the madreporygenous zoophytes would be useless, even were it possible within the limits permitted to us; we shall therefore content ourselves with selecting those genera which have been most attentively examined, and from their history the reader will have little difficulty in obtaining a clear insight into the economy of the rest. Throughout the entire series the vital agent will be found to present itself in the form of a soft, gelatinous crust wherewith the exterior of the polypary, whatever may be its shape, is closely invested, or more correctly speaking, the calcareous particles are gradually deposited in its cellular interstices, and thus moulded into form. Externally this living cortex is generally studded with polypes lodged in cells excavated in the polypary, the forms of which are indicative of the species.

The *Fungiæ*, although their calcareous skeletons are to be met with in every cabinet, have never, as far as we are aware, been brought to our shores in their recent state; and accordingly their living condition has been very erroneously described by several modern writers. The dried framework of the *Fungia agariciformis* owes its name to its similitude to a mushroom, which it closely resembles. In shape it is a circular disc, the inferior surface of which is flat, and rough, and granular, while superiorly it is convex, its upper surface being arranged in broad calcareous lamellæ, which radiate from the centre to the circumference of the mass (*fig.* 38). According to Forskal*, when in a living state, the whole superficies of the Fungia is covered over with a thin gelatinous layer, which dipping in between the radiating lamellæ coat every part of the calcareous surface, but without any polype or appearance of tentacula. The gelatinous coat, indeed, seems exactly to represent the living crust of the sponges, being entirely destitute of anything like a stomachal cavity, and apparently nourished altogether by its general surface, which must appropriate nutriment from the surrounding water. The living film which thus encrusts the Fungia is the only agent employed in the construction of the beautiful calcareous basis that supports it, each particle of which, as it is derived from the circumambient element, is added, by interstitial deposit, to the growing fabric, which is thus built up in the regular form belonging to the species. The upper surface of the living animal has been observed to be provided with bubbles of air, apparently secreted by the living film in which it is imprisoned. These bubbles seem to have no regularity of arrangement, but nevertheless play an important part in preserving the Fungia from destruction; for the mass being in its adult state unattached to any foreign body, is of course quite at the mercy of every passing wave, which, taking it up, might capsize it, and thus bury its upper surface in the sand; but the air bubbles placed there, as it were in anticipation of such an accident, acting the part of floats, always by their buoyancy keep the living side uppermost, and allow the creature to

* Quoy et Gaimard, Voyage de l'Uranie.

* Flora Œgyptiaco-Arabica; Hauniæ, 1775.

Fig. 38.



Fungia. A portion of the calcareous basis has been denuded of the gelatinous coating. (*After Forskal.*)

settle down again at the bottom in its right position.

The living gelatinous crust which covers the surface of the lamella is not merely a superficial investment, as it has been described by some writers, but, as will be proved hereafter, enters essentially into the formation of the substance of the stony mass, upon the component parts of which it exerts a vital influence.

The Fungia described above inhabits the Red Sea, and is entirely destitute of tentacular appendages; but the generality of those brought from tropical climates have their upper surface covered with numerous cylindrical tentacula (*fig.* 39), which, when expanded, give it very much the appearance of a true Actinia. When these tentacula are touched, they shrink, and partially hide themselves between the radiating lamellæ. The stony polypary has in this species been proved to be in reality lodged in the interior of the animal's body, the soft parts of which cover the lower surface as well as the upper, and even form a fleshy ring around the margin of the disc, giving the idea of the foot of an Actinia.

In the centre of the upper surface there is an oval aperture (*fig.* 39), which has been regarded as the creature's mouth; but there does not seem to be any stomachal cavity. The tentacula of some species are so large, that they look something like leeches; they have, however, no terminal orifice, as those of the Actiniæ have, but seem to fill themselves with water by a kind of interstitial absorption.

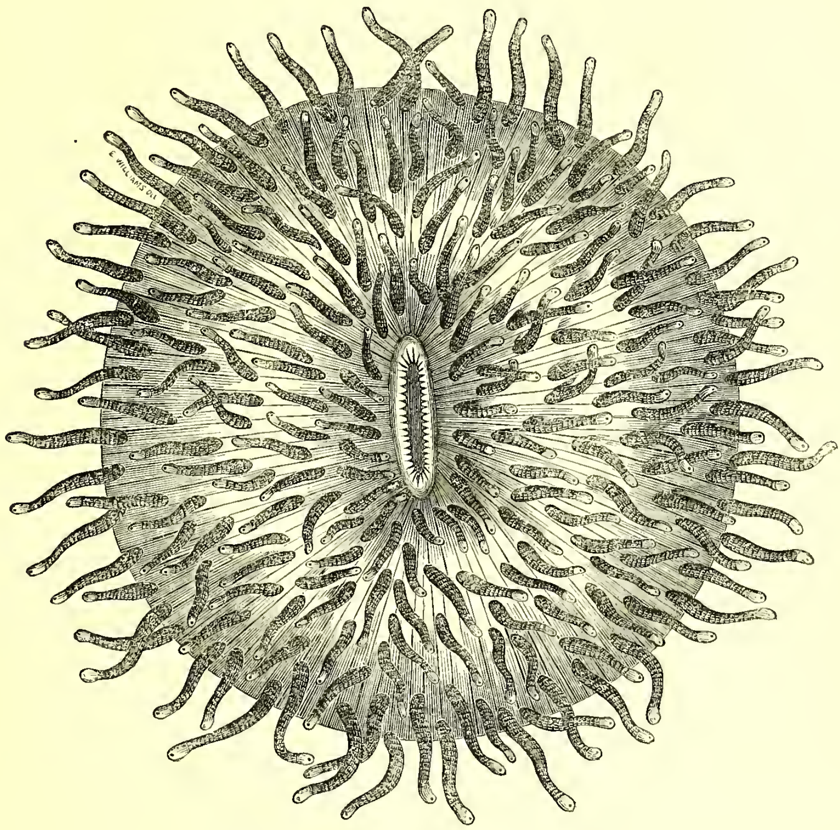
The polype-like investment of a Fungia of this description * is fleshy, membranous, and flattened, generally circular or oval, having in its centre an elongated opening; the animal is thicker at this part than at the circumference. The Fungia then is a broad polype, slightly fringed around its margin, and secreting, by its inferior surface, calcareous matter, imitating all the natural forms of the animal, and even its accidental positions. All the septa are triangular, much thicker at their base than at the summit, where the fleshy crust is so thin, that if the polype is colourless it is imperceptible; but it is distinct in coloured species. Upon the sides of the laminæ are little tubercles, which, penetrating the fleshy folds of the animal, cause it to adhere so firmly to the calcareous basis, that it is impossible to detach it, except by piecemeal. In the natural state, the mouth of the polype is prominent, but it does not project beyond the fissure which contains it; at the least touch the whole creature contracts, so that it would seem that there was no animal. During growth, as the laminæ become more elevated, the interstices are gradually filled up from the bottom; but the increase of the Fungia in thickness is very limited, as, in fact, is its lateral extent, the diameter rarely exceeding six or seven inches.

Generally the gemmules of Fungiæ are developed upon the sand, without, however, ad-

* Quoy et Gaimard, Voyage de l'Uranie.

hering to it; sometimes they are fixed to other madrepores by an elongated pedicle, and occasionally, as we learn from a recent author, grow from the substance of the parent zoophyte. His account is as follows:— "The specimens of *Fungia* which I have seen generally lie in hollows of reefs, where they are in some degree protected from the more violent agitation of the sea by the surrounding portions of branching coral which enclose the hollows, and at the same time allow sea-water free access through their interstices. It appears that although the older and larger individuals are quite unattached and present no mark of former attachment, yet that in the young state they are fixed sometimes to rocks, and frequently to the dead remains of their own species; in this

Fig. 39.



Fungia actiniformis. (*After Quoy et Gaimard.*)

state they grow upon a footstalk, and generally remain attached till they acquire the size of nearly an inch in diameter, when they separate at the top of the peduncle."

"At this time the coral, when divested of the fleshy part, shows a circular opening beneath, through which the radiating plates of the upper surface are visible. In a short time a deposit of coral matter takes place, which cicatrises the opening, the marks of which, however, can be traced for a considerable time; at length the increase of this deposit, which continues with the growth of the animal, entirely obliterates all appearance of it. It will not appear surprising that this circumstance should hitherto have been unnoticed, when it is recollected that it has very rarely occurred to naturalists to visit the places of their growth, and that to general collectors the smaller specimens would appear hardly worth the trouble of preserving and bringing home."

"The sheltered situation in which the *Fungiæ* are found are particularly well adapted to their nature, as they would be liable to injury if they were exposed to the full force of a stormy sea; and the circumstance of their being attached in the young state is a beautiful provision of nature for their preservation at that period, as from their light weight, when first developed, they would, if unattached, be exposed to great injury, even by a slight agitation of the water. I have also to remark upon this fact, that the Fungiæ, while attached, agree in every respect with Lamarck's genus *Caryophyllia*, more especially in their

early state, when the radiating plates are first developed. At this time their upper discs are scarcely larger than the stem, but they soon begin to spread, and show indications of their characteristic form. There are many instances of smaller individuals remaining fixed to large ones in a living state, and such specimens are not unfrequent in collections of corals. But in all cases that I have seen, the younger ones are attached to the under side of the old one, and I believe them to be cases of accidental attachment."

"In Ellis's *Zoophytes* (p. 146) is the following passage, quoted from Rumphius, in regard to the animal of *F. agariciformis*. 'The more elevated folds or plaits have borders like the denticulated edge of needlework lace; these are covered with innumerable oblong vesicles, formed of a gelatinous substance, which appear alive under water, and may be observed to move like an insect.' I have observed these radiating folds of the animal, which secrete the lamellæ, and which shrink between them when the animal contracts itself on being disturbed. They are constantly moving in tremulous undulations, but the vesicles appeared to me to be air vessels placed along the edges of the folds; and the vesicles disappeared when the animal was touched."

"This arrangement of air vessels would very materially assist in keeping uppermost the convex disc of the coral, and be of vital importance to the young polype at the time of separation, and subsequently in keeping it upon the surface of its sandy bed; or if they were moved by a sudden roll of the sea, which would lift even the most ponderous and possibly convey them a considerable distance, they would be again deposited in their natural position. That they have no power of turning themselves I proved, during a sojourn of six weeks at Tahiti, by placing a healthy specimen with its upper surface downwards, during which time it remained in the position placed, and the vitality of the points of contact with the rock upon which it was laid was destroyed. In *Fungia limacina* I have seen instances where the coral, having been accidentally placed and permanently fixed in such unusual positions, has adapted itself to its new situation, by increasing upon its edges, and forming a new convex surface."

"As long as the young *Fungia* retains the form of a Caryophyllia, it is entirely enveloped by the soft parts of the animal; but as the upper disc of the coral spreads and it assumes its characteristic form, the pedicle is left naked, and the soft part extends only to the line where the separation afterwards takes place."

"I consider the cases in which young Fungiæ are found fixed to the under side of others of the same species to arise from the accidental attachment of the young polype when detached from its parent, and by the motion of the water floated underneath a larger one of its own species, the edges of which were not so even as to touch the rock or coral on which it rested at every part of its surface. In such cases the soft parts of the older specimen would continue to cover the short stem of the younger individual, and hence its separation from its pedicle would be prevented."

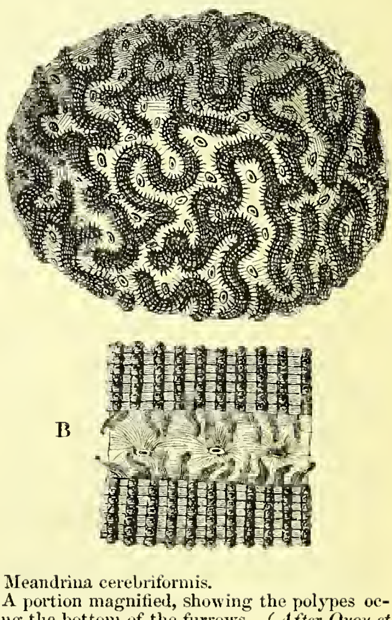
The genus *Polyphyllia* is, in its essential structure, closely allied to the Fungiæ described above, but the upper surface of its stony polypary, instead of being furnished with lamellæ, all diverging from the same centre, is covered with numerous smaller laminæ, diverging from different centres, but generally arranged perpendicularly to the long axis of the polypary. In the living state all the superficies of a Polyphyllia are covered with numerous polypes, the bodies of which are confluent at their margins. Their mouths are placed without any regular order, but open here and there in the depressions that separate the numerous laminæ; they are of an oval or roundish form, and slightly fringed around their margins, but without any tentacula. These latter are distributed over the whole upper surface of the compound animal, and seem to be formed by prolongations of the fleshy substance which covers the more prominent lamellæ, but present no appearance of being arranged round a given centre. When taken out of the water they disappear, shrinking between the laminæ. The polypes themselves in their structure resemble those of the other Anthozoa, presenting the usual arrangement of a stomach and ovigerous filaments.

Very nearly related to the Fungiæ are the *Meandrinæ* (*fig.* 40), the polyparies of which

Fig. 40.

A

B



A. Meandrina cerebriformis.

B. A portion magnified, showing the polypes occupying the bottom of the furrows. (*After Quoy et Gaimard.*)

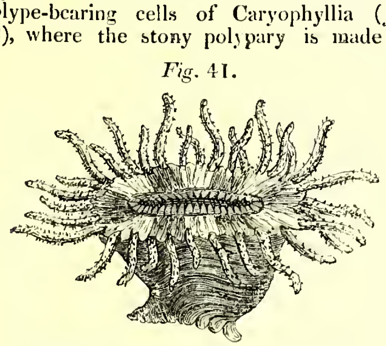
are globular, their surfaces being grooved with sinuous furrows, the meanderings of which give name to the genus. The Meandrinæ have all a determinate growth which they do

not exceed, and consequently their masses are always separate, and not agglomerated like those of Madrepores, Astreæ, &c., which grow indefinitely. The polypes of Meandrinæ occupy the bottom of the furrows, and are variously coloured in different individuals. When attentively examined, they are seen to form membranous expansions, which cover the lamellæ of the ambulacra but rarely mount to the summit of the ridges, the whiteness of which indicates the line of separation between the different rows of polypes. They are, in fact, Caryophylliæ or Fungiæ much elongated. They secrete, from all parts of their body, a mucosity so abundant that, on reversing the mass, it runs off like albumen. The same is the case with Agaricæ and Pavoniæ. When exposed to the sun the living part becomes black by putrefaction.

On splitting the globular stony polypary of a Meandrina, the mode of its growth is very beautifully demonstrated. Commencing at the centre of the mass, the deposition of calcareous matter is seen to have progressed regularly in all directions, layer after layer, like the coats of an onion, every stratum having, of course, in turn been the outer surface of the polypary and marked with the same sinuosities or convolutions as are exhibited by the existing exterior, affording a very striking illustration of the mode of growth common to all the lithophytous zoophytes, and of the mathematical precision with which they build their wonderful edifices.

We are progressively conducted through various intermediate species of laminated zoophytes from the broadly extended disc of Fungia and the diffuse surface of Meandrina to more concentrated forms of these lithogenic polypes. In Turbinolia (*fig.* 41), for example, the superior laminiferous disc is evidently an approximation to the structure of the real polype-bearing cells of Caryophyllia (*fig.* 42), where the stony polypary is made up

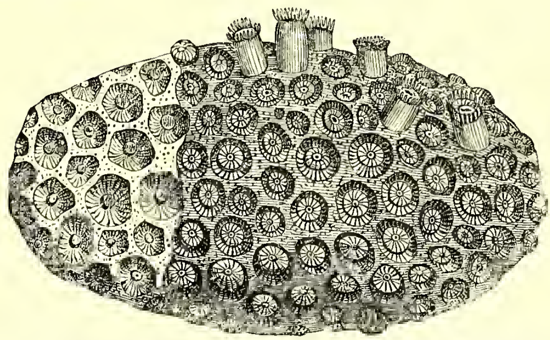
Fig. 41.



Turbinolia rubra. (*After Quoy et Gaimard.*)

of infinite numbers of distinct cells united to each other by an interposed calcareous cement, and every one of them containing a many-armed polype, the essential structure of which is similar to that of the eight-armed species already described; the principal difference between them being in the number of the tentacula, corresponding to that of the radiating lamellæ, wherewith their bases correspond, which, in the many-armed species,

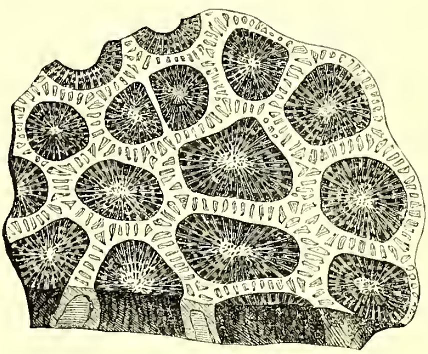
Fig. 42.



Caryophyllia fasciculata. A portion of the calcareous polypary has been denuded. (*After Quoy et Gaimard.*)

are numerous. Another important circumstance in the economy of these races of zoophytes is, that the radiating lamellæ contained in the abdominal cavity situated beneath the stomach are progressively calcified from below upwards, and thus become converted into stony plates instead of membranous septa, so that on making a section of these polyparies perpendicular to the axes of the cells, each cell presents the appearance represented in *fig.* 43; and even in fossil polyparies,

Fig. 43.



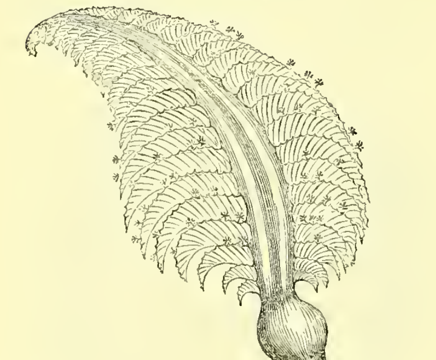
Section of calcareous polypary of Astrea abnormalis. (*After Quoy et Gaimard.*)

where the whole substance of the mass has become solidified, the original radiating laminæ are permanently conspicuous, as many a marble chimney-piece will testify. In their living state the polypes inhabiting these cells are most variously and gorgeously coloured, so that when protruded they are indescribably beautiful, resembling the flowers that adorn the gayest parterres in our gardens. Yet if such be the interest of this spectacle, even to the eye of the ordinary observer who amuses himself by contemplating the indications of life exhibited by a little patch of a coral reef, what

must be the feelings excited in the mind capable of appreciating the result of the labours of these silent agents in the economy of our world! Let us imagine for a moment the stupendous scene which the mental eye may view at the bottom of the ocean. Vast districts of the globe spread over with a carpet of this living crust, studded, as thickly as are our fields with grass, with hungry flowers of every various hue — all actively employed in carrying on the great progressive work — depositing, with unobtrusive diligence, from age to age, the chalky masses we have been describing—slowly, but unremittingly, the mighty fabric grows, until at length it peers into the world above the waves which nourished it, and forms a land where all before was sea, soon to be peopled with fit occupants, or possibly by the volcano's breath upheaved into the clouds, to become the nucleus of a country like our own, from which intelligence may pour forth to irradiate the world!

Pennatulidæ. — The Pennatulæ, or Sea-pens, are distinguished by Cuvier from the other families of cortical polyps under the title of "Polypiers nageurs," or swimming Polyparies, and are remarkable from the circumstance that, although they possess an internal calcareous support, they are not attached to foreign bodies, but seem at liberty to swim about in the sea. The Pennatulæ, properly so called, several species of which are met with on our own shores (*fig.* 44), have a

Fig. 44.



Pennatula grisea. (*After Blainville.*)

central stony axis, coated over its greater part with a thick living cortex, the substance of which presents a somewhat fibrous arrangement, and is capable of movements of contraction sufficiently forcible to permit of locomotion. The lower portion of the stem, which strikingly resembles the barrel of a quill, is entirely denuded of this living crust, and when found in the bays upon our coast, this part is generally stuck into the mud at the bottom like a pen into an inkstand, whilst the two upper thirds of the stem are furnished on each side with broad lateral appendages, comparable to the barbs of a quill, from the margins of which are protruded the rows of polypes which minister to the support of the common body of this compound animal. The lateral barbs are supported by calcareous spicula developed in their interior and imbedded in their fleshy substance, but having no other connection with the central stem.

In other genera the alary appendages are without any internal spines, or sometimes entirely wanting, in which case the polypes are situated upon the stem itself.

In *Renilla* the body consists of a broad kidney-shaped disc without any barbs, the polypes in this case being distributed over one surface of the disc, and in *Veretillum* the polype-bearing part is a cylindrical finger-shaped mass. The central axis in both the last-named genera contains but little calcareous matter, and in the whole family the individual polypes closely resemble those of the Alcyonidæ in their organisation. In *Veretillum* the substance of the general mass is excavated into wide canals that extend in the direction of the central axis of the body, and terminate in wider cavities within the lesser obtuse extremity.

Many of the Pennatulidæ are eminently phosphorescent.

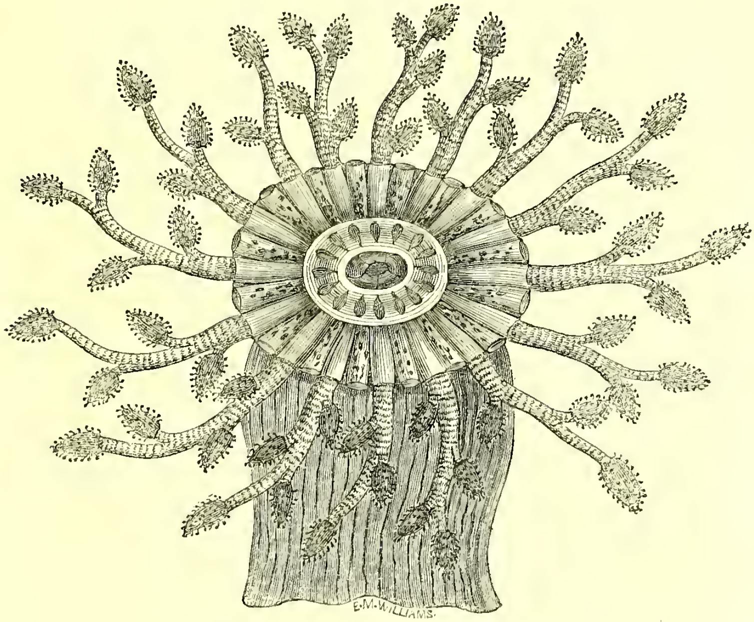
The polypes of this group of cortical zoophytes have eight pinnated arms, and seem to be organised upon the same plan as those of the Corallidæ.

Actiniadæ. — The *Actiniæ*, or Sea-anemonies, so common on our coasts, known also by the name of "fleshy polypes," are evidently nearly allied to the preceding family, but instead of secreting a calcareous polypary have their bodies entirely composed of a fleshy substance which, in appearance at least, is not very remote from muscular fibre. The ordinary Actiniæ are of a conical form, the base of the cone forming a strong sucker, whereby they attach themselves to foreign bodies, while, at the opposite extremity, which is truncated, is the opening of the mouth, surrounded with several rows of retractile tentacula, wherewith they seize their prey. They often elongate their bodies, and, remaining fixed by their base, they stretch from side to side as if to seek for food at a distance, and when thus stretched out they are very flexible and transparent, but shrink on being irritated, and contract themselves so firmly that it becomes almost impossible to distinguish them from the surface to which they are attached. According to some writers they can change their place by gliding upon their base; or detaching themselves entirely, they become swollen by the imbibition of water, and thus being rendered nearly of the same specific gravity as the surrounding element are driven about in the sea until they choose to fix themselves again, when, by expelling the fluid from their bodies, they sink again to the bottom, and settling down become again fixed. It is even asserted that having detached their suckers they can turn

themselves mouth downwards, and crawl by means of their tentacula, but our observations have failed to confirm these remarks.

The substance of the Actinia is entirely composed of transverse and perpendicular muscular fibres, which cross each other, the meshes of this interlacement being occupied by a multitude of granules, seemingly of a glandular nature, giving to the surface of the polype, which is covered with a gelatinous membrane, a tuberculated appearance. Externally this fibrous membrane forms the parietes of the creature's body, expanding inferiorly into the basal disc, and superiorly, after forming a sphincter-like ring around the tentacula, is continued inwards to form the tentacula themselves (*fig.* 46, *a*), and then, becoming more delicate in its texture, reflected

Fig. 45.



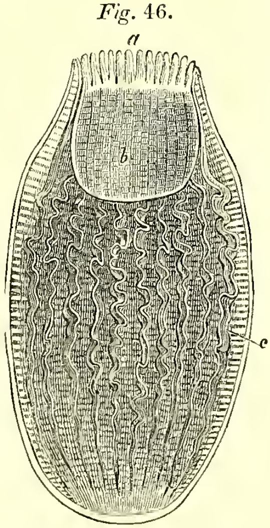
Actinia alcyonoidea. (*After Quoy et Gaimard.*)

into the interior of the body so as to form the stomachal cavity (*b*). Extending between the internal surface of the outer walls of the body and the exterior of the stomach are numerous longitudinal septa (*c*), evidently the homologues of the vertical partitions of the Alcyonide (*fig.* 31, *f*), and were these calcified by the deposition of stony matter in their interior they would represent exactly the radiating septa in the cells of the polypary delineated in *fig.* 43.

As in the preceding genera these membranous septa support the organs of reproduction, which are constructed after the following manner.*

The whole interior of the Actinia, between the stomach and the muscular parieties of the body, is divided by means of the septa into numerous longitudinal cavities, each of which communicates with the bases of two or three of the tentacula around the mouth † and encloses an ovary. Each ovary is composed of three or four cylindrical and coherent tubes of extreme delicacy, which, towards the base of the

Fig. 46.



Section of "Actinie Clou."

a, Tentacles surrounding the mouth; *b*, stomach; *c*, longitudinal septa prolonged and enclosing the ovaries. (*After Quoy et Gaimard.*)

* Spix, Annales du Museum d'Hist. Nat. tom. 13.

† For an admirable diagrammatic representation of the structure of Actinia, the reader is referred to Dr. Sharpey's Article "Cilia," Vol. I. fig. 297.

animal, are prolonged into a common canal, their opposite extremity tapering to a point as the eggs become smaller, each ovary containing about sixty eggs. The common tubes of two neighbouring ovaries unite into one as they issue from the longitudinal cavity, and this again joins the common canal of the next pair; the resulting duct, which is thus common to four ovaries, opens into the stomach. The openings of these terminal tubes are arranged in a zig-zag direction, some opening lower down, others higher up.

Reaumur* believed that the young issued by a slit on each side of the body, situated beneath the fold of the muscular envelope that surrounds the bases of the tentacula, but the supposed openings are merely folds of the skin, never perforate, and not always present. Nevertheless, as the tentacula are perforate at their extremities, and water is frequently forced out of the body through these openings, it is possible that some ova may become detached and issue through these organs.

The ova are round, yellow, and like little grains of sand. Ellis, Reaumur, Dicquemare, and Spix, all assert that Actiniæ are viviparous. The latter observer states, "I have several times seen them issue from the mouth of their parent perfectly formed. An Actinia that I have in spirit of wine contains a great number of eggs, each marked with an opaque spot that seems to contain the young animal. I have even one individual not larger than a hemp-seed, which seems hardly ready to quit its envelope, having neither the mouth nor the tentacula perfectly distinct. Moreover, I suspect that the eggs are sometimes hatched in the ovaria or in the stomach, and sometimes out of the parent. I am not sure but the animal may at the time of the expulsion of the eggs have its stomach turned inside out."

The number of eggs must be prodigious, each Actinia possessing upwards of a hundred ovaria.

It appears from recent researches that the Actiniform polypes are bisexual.

It is rendered extremely probable by the very advanced condition of the muscular apparatus in the Actinia that they likewise possess a nervous system. Spix in his experiments employed galvanism, which made the animal contract convulsively, and finding that the contractions were strongest in the neighbourhood of the base of the animal he was led to search for it in this part, and conceived that he had discovered it in this situation. "Having raised by a slight incision the longitudinal muscles at their union in the middle of the base, I perceived with a magnifying glass an interlacement formed by some pairs of nodules disposed around the centre which communicated by several cylindrical threads; from each nodule two filaments ran forwards; one was seen to run along the muscle, the other to pierce it, to divide into two branches, and, lastly, to lose itself in the longitudinal cavity formed by the floating muscles. The situation of the nodules and filaments is beneath the stomach, and their round figure would not allow me to confound them with the muscles, which are broad and riband-shaped, and still less as the latter putrified rapidly, while the former remained entire."*

Some of the tropical Actiniæ†, which occasionally measure a foot in diameter, produce a stinging sensation when they are handled, and this stinging property is even communicated to the water that they absorb. There is moreover one remarkable circumstance connected with it; namely, that it acts much more powerfully upon the skin, which it inflames, than upon the mucous membranes, and a drop received into the eye causes much less pain than when applied to the eyelids.

The Actiniæ, although exceedingly voracious, will bear long fasting: they may be preserved alive a whole year, or perhaps longer, in a vessel of sea-water; but when food is presented one of them will devour two mussels in their shells or a crab as large as a hen's egg. In a day or two the shell is voided at the mouth perfectly cleared of the meat.

Their power of reproducing lost parts is scarcely inferior to that of the Hydræ. The Abbé Dicquemare ‡ describes some experiments on this subject, and states that when a horizontal section is made through one of these creatures the tentacles still seized and swallowed food, which sometimes passed through the body, at other times was expelled from the mouth digested. In about two months tentacles grew from the other portion, and it ate food, soon becoming a perfect animal. He states that in this way he even succeeded in making an Actinia with a mouth and tentacles at both ends!

AULOZOA. — The third subdivision of POLYPIFERA is composed of a series of zoophytes very different in their organisation from those embraced by the two preceding. They have generally been named by naturalists Tubular or Vaginated Polypes, and are distinguishable from the circumstance that their living substance, instead of being external to the hard polypary, is in them enclosed in a calcareous or corneous tube, sometimes simple, but more frequently ramified, from which the polypes are protruded, either through a terminal aperture or from lateral cellules formed by the external envelope.

The *Aulozoa* are divisible into several groups, which we shall separately examine, beginning with the *Tubularidæ*.

In the *Tubularia* (*fig.* 48), as in all polypes unprovided with a complete digestive canal, there is an organic portion which brings all the members of the colony into communica-

* Histoire de l'Académie des Sciences Naturelles, An. 1710.

* Spix, Ann. du Mus. d'Hist. Nat. vol. xiii. p. 444.

† Quoy et Gaimard.

‡ Phil. Trans. for 1773.

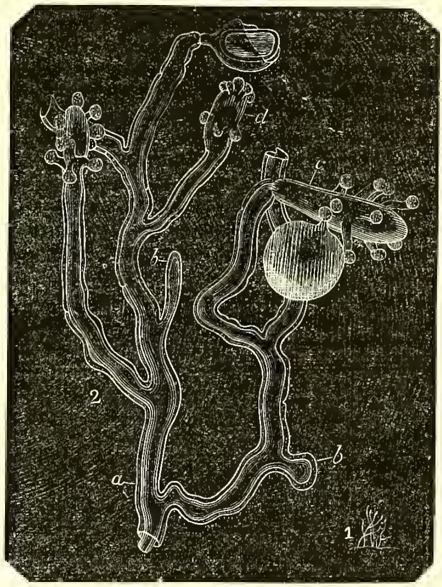
tion with each other, or forms in other words the body of the community, and from this common body buds are thrown out, from which ramifications are produced in all respects resembling those met with in the vegetable kingdom; these constitute the trunk and branches of a tree, which, instead of bearing flowers, produces polypes provided with tentacula, a digestive cavity, and most frequently a reproductive apparatus.

Tentacular apparatus. — In the Tubularidæ the tentacula are situated, as in all polypes, around or in the immediate vicinity of the oral opening. Their number is very various, even in the same species, but the variations in their length are more apparent than real, for their contractile powers are such that they are constantly changing in their shape and dimensions, in which respect they resemble the Hydra described above. It is towards the extremity of the tentacle that this contractile power is most remarkable; and when the organ is not fully stretched out, it is enlarged or dilated near the end, insomuch that some authors have erroneously looked upon this part as performing the office of a sucker.

The disposition of the tentacula varies in different genera. The genus *Eudendrium* has a single row of tentacula, which are alternately placed a little more internally and externally. The genus *Tubularia*, properly so called, has a second row of shorter tentacles immediately surrounding the proboscidiform prolongation which constitutes its mouth, and in the genus *Stipula* (Sars) there is an additional row situated between these two, so that there are genera with one, two, or several rows of tentacula; the lower row is, however, always the longest, and it is these that are persistent when there is only one rank. The tentacula are arranged in whorls in all the Tubularidæ, except in the genus *Syncoryna*, in which they are distributed without regularity (*fig.* 47). No cilia are perceptible, either externally or in the interior of these tentacula, which, when highly magnified, appear to be entirely composed of transparent cells, closely agglomerated, and no traces of muscular fibre are by any means to be detected; their movements seem to depend entirely upon the contractions of their component cellules, which are seen to diminish in size when the tentacle is shortened, and to expand during its elongation, preserving nearly the same shape, whence it may be concluded that their parietes are endowed with contractile powers. Professor Van Beneden indeed compares them to so many hearts placed end to end, which, by their dilatation elongate, or by their constriction shorten or bend, the tentacle of which they constitute the substance.

Digestive system. — In the Tubularidæ there is seen, situated in the middle of the tentacula, a sort of proboscidiform appendage, open in the centre, which is the entrance to the digestive cavity. The name of proboscis appears sufficiently applicable to this part, both on account of its situation and of the changes of form which it continually undergoes. In its most usual condition it has the appearance of a protuberance provided at its summit with an orifice of very variable shape and size.*

Fig. 47.



Syncoryna pusilla.

1. A little group, twice the natural size. 2. A branch much magnified. *a*, the stalk; *b*, a bud from which a polype is about to be developed; *b*, a bud which is about to give rise to a long stalk; *c*, body of the Syncoryna with its three rows of tentacula; *d*, a Syncoryna having only two rows of tentacula. (*After Van Beneden.*)

The cavity of the proboscis leads into that of the stomach, but neither the one nor the other have parietes proper to themselves, but on the contrary seem, as in the Hydra, to be mere excavations in the substance of the polype. In the genus *Coryne*, the cavity of the stomach is circumscribed, so that each polype has a proper digestive cavity; but in all the other genera belonging to this family, the stomachal receptacles of different individuals communicate mediately one with another, so that what is taken into the stomach of one polype may pass into those of all the individuals composing the colony. Thus, what is eaten by a few individuals profits the whole community, seeing that what one swallows may pass into the stomachs of its neighbours.

When we examine a young branch that is sufficiently transparent, a fluid containing irregular globules is seen to circulate in its

* Récherches sur l'Embryogenie des Tubulaires, et l'Histoire naturelle des différents Genres de cette Famille qui habitent la côté d'Ostende, par P. J. Van Beneden, Mem. de l'Acad. Royale de Bruxelles, 1844.

interior. There is no intestinal canal, all excrementitious matters being evacuated through the oral orifice.

Circulation.—The stems of the *Tubularidæ* are formed of the same kind of tissue as that which constitutes the body of the Polype, and each stem is hollow throughout its entire length. The tube thus formed is filled with a fluid containing globules, which is constantly in motion, a circumstance first observed by Lister *, but its course is by no means regular. Sometimes the globules mount up as far as the body of the polype, and then descend again by the same route; if they come to a division of the stem, as is frequently the case in most genera, they may be sometimes seen first to penetrate into one branch, and then returning enter the other. In the ordinary Tubularia, described by Lister, a current may generally be seen ascending along one side and descending along the other. In the long and slender stems of *Eudendrium*, which are very transparent, Professor Van Beneden has observed the fluid containing globules mount from the base towards the summit for some instants, when the circulation seems to become suspended for a time; but soon the globules begin to move in the opposite direction, descending from the summit towards the base; shortly after it again mounts as at first, and thus the circulation goes on alternately up and down. This movement of fluid in the stem Professor Van Beneden is disposed to attribute to ciliary action, although no cilia are discoverable by the microscope; still, without such mechanism, it is difficult to account for two distinct currents running in opposite directions in the interior of the same tube, which exhibits not the slightest trace of a septum between them.

There seem to be no organs specially appropriated to *respiration*.

With the exception of the genera *Coryne* and *Hydractinia* all the Tubularidæ are provided with an external tubular sheath, or polypary, which is thin and semitransparent; its texture is corneous or pergamentaceous, and very flexible. The polypary of the genus *Tubularia* is generally described as being a simple tube without any ramifications; this, however, is only true in the case of young individuals inhabiting isolated stems. In old specimens the polypary is ramified at its base, and is only straight and simple at its free extremity.

Reproduction.—In all the genera of this family the reproductive organs consist of groups of little pedicles growing in the vicinity of the tentacula, which support little rounded bodies, often united together in bunches, which when mature fall off like fruit from a tree, and are dispersed to form new colonies. It is a true animal seed, which the waves carry to a distance and disseminate in all directions, and the whole observable reproductive apparatus consists of the organs that produce these rounded corpuscles or ova. Yet simple as this arrangement of the reproductive system may appear, we learn from the researches of Professor Van Beneden that the propagation of the *Tubularidæ* is effected by no fewer than five different modes; namely,

1. By continuous gemmation.
2. By the production of free gemmæ.
3. By simple ova.
4. By ova with a multiple vitellus.
5. By free gemmation and ova combined.

Observation has moreover shown that in every species propagation is effected by more than one of these modes of reproduction, and sometimes by three or four; and it must be remarked that in none of them is the cooperation of a male apparatus requisite, neither have any male organs or spermatozoa been as yet detected.

First mode of propagation, by continuous gemmation.—This is the ordinary form of gemmiparous generation, whereby a colony is developed by sprouts derived from a single individual; the appellation "continuous gemmation," is applied to it by Professor Van Beneden, to distinguish it from the second mode of reproduction by free gemmæ.

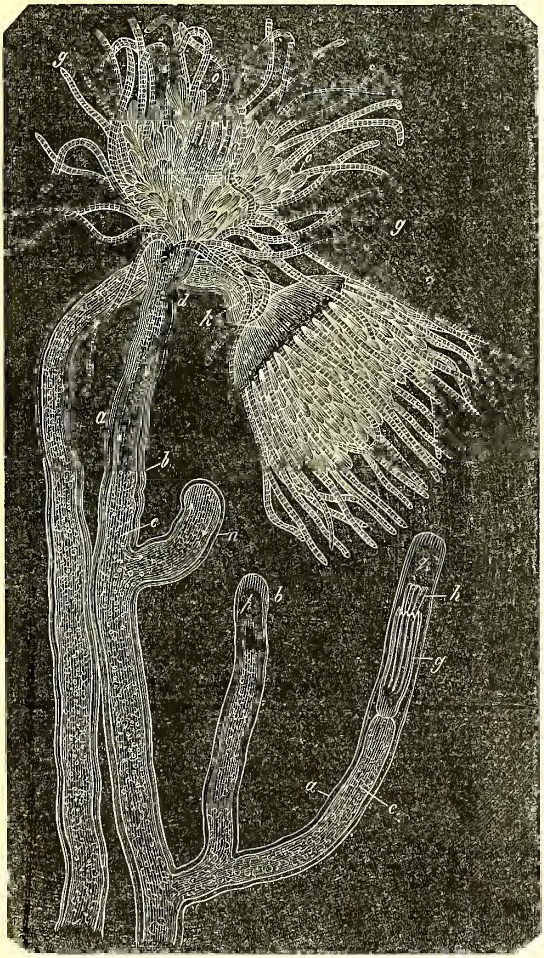
This method of propagation is the simplest possible, and is effected by mere growth from the original polype in certain determinate points of its substance, which points are similarly situated with respect to each other in all the individuals belonging to the same species. At these points gemmæ appear exactly similar both in texture and mode of growth to the body from which they spring; and these buds as they grow give birth to others in a precisely similar manner. All these animals, be it remembered, are, like the Hydræ, capable of being reproduced by the mechanical division of their bodies, so that if one be cut into several fragments, each portion may give rise to a new individual; every part of their structure is endowed with a reproductive power comparable to that which is conferred only upon the eggs of the superior animals; whence we might almost be induced to regard the different cells composing their bodies as analogous to ova, and the polype itself as a mere aggregation of germs. It is upon the definite points whence these buds sprout that the particular characters of the Polyparies depend, else they would mostly resemble each other, for at their first production there is little difference to be observed between them.

In like manner when a stem is cut off transversely, a bud is developed from the cut extremity, which by its growth prolongs the original trunk. When this kind of gemma has attained to a sufficient size there arises from its extremity a little crown of tubercles, and subsequently a second becomes manifest at some distance from the first; and as the growth of these tubercles continues, each of them becomes at length developed into a tentacle. The tentacle, therefore, grows from the body exactly in the same way as the bud from the stem, the only difference being that the former is solid, and the latter tubular.

* Phil. Trans. for 1834, pt. 2.

The growth of the horny polypary exactly keeps pace with the development of the soft substance, and even goes beyond it. Below the tentacula the body soon becomes constricted, marking the boundary between it and the stem; and soon the polype, becoming too large to be contained in its sheath, issues forth, and expanding its tentacula becomes perfectly unfolded. The oviferous pedicles, hereafter to be described, are developed subsequently.

Fig. 48.



Tubularia coronata, magnified.

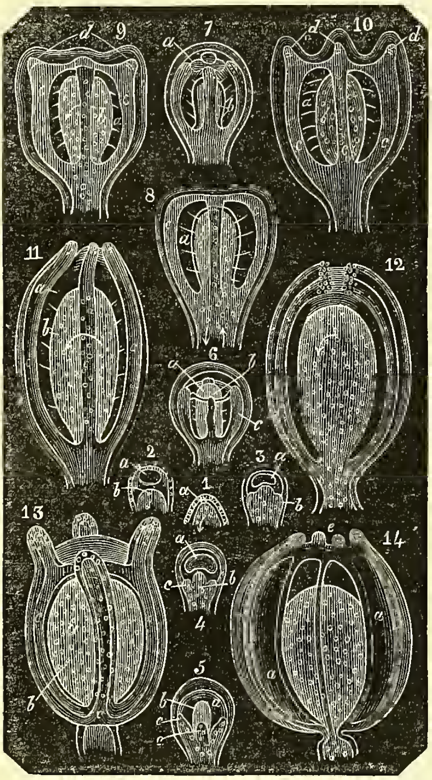
a, stalk; *b*, walls of the polypary; *c*, substance common to all the individuals, whereby they are brought into mutual organic communication; *d*, limit between the individual and the community; *g*, the long tentacles; *h*, the short tentacles; *k*, collar formed by the tentacles; *o*, ova; *n*, a bud; *p*, a bud further developed; *q*, a bud still further advanced, showing indications of the two rows of tentacles (*g*, *h*). (*After Van Beneden.*)

Second mode of propagation, by free gemmæ. —The free gemmæ are produced upon distinct pedicles, which in the genus Tubularia are developed within the lower circle of tentacula. They resemble numerous appendages disposed in a circle and forming a crown around the body of the polype. (*Fig.* 48, *o.*) These pedicles grow in the same manner as the buds and the tentacula described above, that is to say, a hollow tubercle first makes its appearance, which seems to be merely an extension of the external covering of the polype. Each tubercle slowly expands, and soon divides into one or more branches, which are all hollow, and the same fluid which circulates in the general substance of the polype may be observed to pass into their interior.

At the free extremity of each of the pedicles thus formed a distinct cell is soon perceptible, situated immediately beneath the surface, which cell is the rudiment of a new individual. (*Fig.* 49, 1, *a.*) No nucleus has been remarked in its interior. This primitive cell, which might also be regarded as an egg or as an ovule, sometimes becomes organised internally, in which case the reproductive process assumes the third or the fourth form, subsequently to be noticed, or else it serves for the point of departure, or it might almost be said the mould for the formation of a free gemma, which becomes organised around it at the expense of the pedicle itself. It is in effect a part of the reproductive appendage that will subsequently become detached; but at this period of its development it is impossible to determine after which of the four modes of reproduction the embryo will be formed. The vesicle (*a*) now increases rapidly in size, and beneath it another membrane is soon perceptible, which by its inner surface is in contact with the circulating fluid. This membrane is the origin of the new individual, or, in other words, a blastoderm, formed by the internal skin, and not by the vitellus. Soon there is seen, projecting from its centre, a little cone (*fig.* 49. 3, 4), which, compressing the vesicle (*a*), forms a depression upon its inner surface, and the vesicle now begins to assume the appearance of a serous membrane, yielding to the pressure of the organs over which it spreads, and ultimately covers, much in the same way as the pleura covers the lungs. The tubercle (*b*) will afterwards form the walls of the digestive cavity, and may be seen to have the circulating fluid derived from the body of the polype moving in its substance. Around the base of the cone (*b*) may now be seen four other tubercles (*c*, 4, *et seq.*), which become developed like the preceding; but, instead of compressing the vesicle (*a*), they surround it, and ultimately completely enclose it. They carry the skin with them, so as to have the appearance of a transparent vase, having four

longitudinal prominent bands, the free edge slightly enlarged and rounded, a pedicle in the middle like the stem of the vase, and the transparent vesicle lining its interior throughout.

Fig. 49.



A series illustrating the development of Tubularia by free gemmæ, from the first indication of the bud to the time when it becomes detached.

1. A hollow tubercle or elevation, in the interior of which a movement or circulation of the globules, indicated by the arrow, takes place; *a*, a cell just beneath the surface.
2. The same, showing the cell more advanced; *a*, indicates this cell in all the figures.
3. This, and the following figures, represent the development of the gemma more and more advanced; *b*, a tubercle, situated beneath the cell, which becomes the stomach of the embryo; this organ is indicated by the same letter in the other figures.
4. *c*, tubercles shooting up from the sides; they are hollow, and communicate with the cavity of the stomach, and are the first indication of four vessels proceeding from the stomachal cavity. In the following figures the letter *c* indicates these vessels.
5. *b*, the tubercle become more elevated, indenting the cell *a*; the four secondary tubercles, *c*, more distinct and prominent.
6. The stomachal and its four surrounding hollow tubercles still further prolonged.
7. In this figure the four smaller tubercles have become vessels, and united with one another in front.
8. The four vessels have more completely united in front; the arrows here, as in the other figures, indicate the current of the circulating fluid.
9. *d*, The first indications of the tentacles, consisting of tubercles sprouting from the four vessels.
10. The tubercles, *d*, at the end of the four vessels, *c*, have become sufficiently elevated to make a projection on the exterior.
11. These tubercles, become considerably salient externally, are now manifestly the four tentacles of the embryo.
12. Minute cells are now visible at the extremity of the tentacles.
13. The tentacles still more advanced; the line of separation of the embryo from its stalk become distinctly visible.
14. Hitherto the stomachal *cul-de-sac* has progressively increased, it now begins to diminish, and the cell *a*, or the space between it and the external envelope becomes opened at *e*, forming a kind of mouth; the embryo is now capable of great extension; the pedicle is constricted at the point of insertion and its internal cavity nearly obliterated. (*From Van Beneden.*)

The different phases of the development above described will, however, be best understood by a reference to the series of figures which we have appended, carefully copied from Professor Van Beneden's elaborate illustrations.

The young *Tubularia* has now assumed the appearance of a *Beroe*, and in this condition has doubtless been often mistaken for an individual belonging to the class Acalephæ; and lively contractions of its body are frequently witnessed, although it still remains attached to its pedicle.

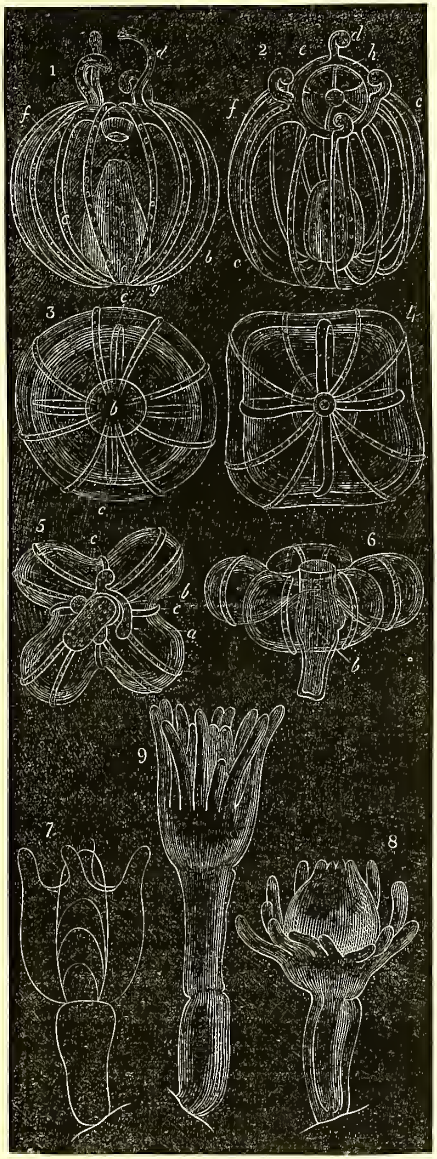
At the extremity of each of the four longitudinal vessels a little tubercle now becomes developed, which, as it becomes elongated, is converted into a tentacle, or sometimes, as in *Eudendrium*, by its bifurcation, two tentacula are formed from each tubercle.

At this period of its development the young *Tubularia* spontaneously detaches itself from the parent stem, presenting at the moment of its separation the appearance of a balloon, or rather of a melon. (*Fig.* 50. 1, 2, 3.) Its contractions become more and more lively, and it is by the aid of these movements that its separation is effected. The two poles of its globular body may be seen to approach each other, and to separate alternately, with a movement of systole and diastole similar to what is observable in many Medusæ. No traces of cilia are observable either externally or in the interior of its body. In this condition it presents an external covering, which is, so to speak, merely a derivation from the integument of the parent polype: this covering presents somewhat more consistence than the internal parts, and is open in front.

A second membrane lines the preceding throughout its whole extent; like the former, it is quite transparent, and at the anterior opening (*e*) is prolonged internally to a little distance, forming a sort of funnel. These walls enclose four vessels (*c*), which extend from the base of the embryo and open in front into the hollow zone (*h*), from which the tentacula take their origin. These longitudinal vessels therefore communicate with each other by a transverse canal, and at their origin open into the central or digestive cavity, which

will, presently, be more particularly described. From this disposition it results that the contents of the stomach can pass as far as the extremities of these four vessels, and by means of the transverse canal ean be transferred from one to the other. Professor Van Beneden observed a fluid containing globules moving in this direction in their interior. The communication between the longitudinal vessels and the stomaehal cavity, and their intercommunication by means of transverse canals, is another arrangement exaetly similar to what exists in the adult Medusæ.

Fig. 50.



A series illustrating the development of Tubularia by free gemmæ, after the detachment of the embryo from its peduncle, in continuation of that in the preceding cut. The same letters indicate similar parts in all the figures in this and the preceding series.

Fig. 1. An embryo detached and moving in the water like a Medusa, seen in profile; in addition to the four vessels, whose development is demonstrated in the foregoing series, eight other canals (f) are now perceptible; these belong to the external envelope.

2. The same viewed obliquely, showing the situation of the mouth e; h, the transverse canal which brings the four vessels into communication.

3. The same seen from below.

4. The four bands or vessels contracted a little, giving to the embryo a subquadrate outline; viewed from below. The embryo is now no longer spherical, but flattened, as well as subquadrate.

5. The embryo viewed obliquely from above; the superior and inferior parietes drawn together; the stomach projecting through the mouth. It now presents the form of a Greek cross, owing to the great contraction of the longitudinal bands or vessels.

6. The embryo placed inverted with respect to *Fig.* 1; the stomachal *cul-de-sac*, which becomes the body of the polype, completely protruded.

7. An ideal transitory figure.

8. The embryo become fixed. The internal row of tentacles beginning to protrude.

9. The same more advanced. The two rows of tentacles further developed.

The outer membrane presents eight longitudinal canals, which are found to be filled with eellules, but in which no movement has been observed. It is to the presence of these longitudinal bands that the embryo in this stage of its development owes its resemblance to certain fruits, more partieularly to a melon.

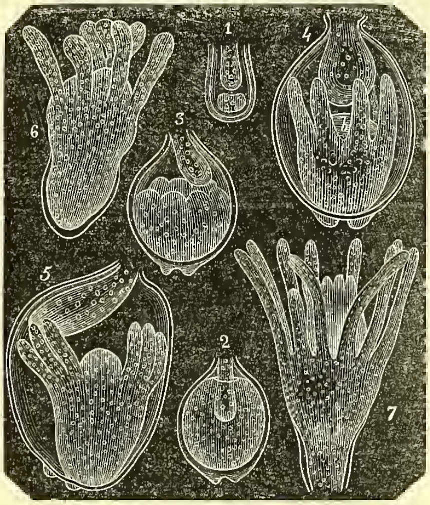
From the anterior part proceed four appendages (d), whieh were still undeveloped at the period of the detachment of the young polype, but which insensibly unfold themselves. These are the tentacula. In the centre there projeets a rounded opaque body (b), generally of a red or yellowish tinge, which is the stomach. This viseus communicates, as has been stated above, with the four longitudinal vessels, and is the only opaque part of the embryo. It opens in front by an orifice which constitutes the mouth; the whole organ is eminently contractile, turning itself in all directions like the body of a Hydra, sometimes elongating itself like a worm, and at others shrinking so as to be almost imperceptible.

If the embryos examined in this condition be vigorous, their movements are very varied, and the forms that they assume extremely singular. The regular contractions above noticed are the most simple actions; the two poles separate and approach each other alternately, whence results the progression of the little creature. But this eontraction may be carried to a still higher degree: the rounded stomach in the middle of the embryo not only contracts itself in every direction, but it seems to turn itself in the middle of its transparent envelope like a worm in search of a passage by which to get out; and at length it pushes its free extremity through the opening in front of it, and elongates its body still more until

the two poles of the balloon becoming approximated, the whole embryo becomes somewhat disc-shaped, or the four vessels that communicate with the stomach (if vessels they really are), by moderately contracting, form as many depressions dividing the embryo into four lobes (*fig.* 50. 5, 6.), or by a more forcible contraction give it the appearance of a Greek cross, and all these changes of form may take place in a few seconds.

Observations are wanting relative to the manner in which the free embryo is converted into the fixed *Tubularia;* for although Professor Van Beneden observed the latter at a very early period after they had become attached, he was unable to witness the changes that they undergo at the moment of becoming attached to some foreign body, and therefore gives a hypothetical outline of the forms through which he supposes them to pass (*fig.* 50.7) preparatory to their final establishment as young Tubulariæ (8, 9).

Fig. 51.



A series showing the development of Tubularia coronata from ova.

1. A ramification or bud of the ovary. The common cavity continued into it as a *cul-de-sac*, beyond which is the ovum.
2. The ovum becomes much enlarged, and surrounding the *cul-de-sac.*
3. The *cul-de-sac* turned aside by gentle compression. Indentations on the ovum indicating the formation of tentacles.
4. An elevation (b) in the centre of the tentacles become perceptible, which afterwards forms the proboscis-like part of the animal.
5. The same compressed between two plates of glass.
6. The embryo after its escape from the ovisac, having as yet but one row of tentacles.
7. The young animal become fixed. The short tentacles beginning to project at the anterior prolongation or proboscis.

Third mode of propagation, by simple ova.— This mode of reproduction approximates the nearest to what occurs in the higher animals. Cells are observed to become organised in the middle of a vesicle in the same manner as the vitelline cells, and to become converted into an embryo. In this case the vitelline cells become aggregated and modified, so as to give rise to a new individual, which is isolated from the commencement of its existence. The point of departure for the formation of the embryo is the same as in the preceding mode of development, and the reproductive vesicle has at first precisely the same structure as in the last case, but instead of preserving its transparency, this vesicle soon exhibits numerous cells, which render it more and more opaque, and give it more the appearance of a vitellus. In this case moreover there is a great difference in the relations which the red pedicle (*fig.* 49, b) bears to the embryo. In the preceding mode of development this pedicle constitutes an integrant part of the newly formed being, forming, in fact, its stomach, but in the oviparous mode there is no organic connection between the one and the other, the vitellus being formed between the pedicle and the integument of the offset, and on pressing the latter between two plates of glass these structures readily separate without any laceration.

As the vitellus increases in size it becomes impacted between the integument and the pedicle, and its augmentation of size still increasing, the upper part of the pedicle becomes covered with it as with a hood, and at last almost entirely enveloped by it. At this period the margins of the vitellus become indented on that side nearest the pedicle, and the tubercles between the indentations soon show themselves to be the rudiments of tentacula. The tentacula become more and more elongated, the embryo separates itself slightly from the pedicle, and a protuberance (*fig.* 51. 4, b) is then perceived in the centre of the tentacular zone, which becomes the proper body of the polype, or rather forms the walls of its stomachal cavity.

The walls of the bud, which has hitherto contained the embryo, now become ruptured, and it gains its liberty (*fig.* 51. 6). In this condition it almost exactly resembles a young Hydra in its contracted state, and in fact both its body and its tentacula seem to have the same anatomical structure as those of that simply organised polype. Having attained to this condition its development proceeds rapidly, and it soon begins to assume the specific form of the Tubularia from which it sprung (*fig.* 51. 7).

Prof. Van Beneden likewise witnessed the same mode of propagation in *Syncoryna pusilla.*

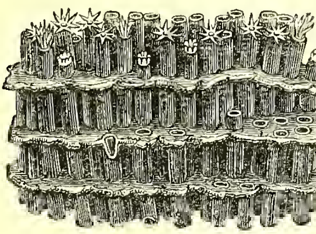
Fourth mode of propagation, by ova with a multiple vitellus.— The fourth mode of reproduction observed by Professor Van Beneden to occur among the tubular polypes is extremely curious. In this form, as in that last described, the young individuals are developed from ova, and the first steps of the process are precisely similar. A bud is formed from the surface of the parent zoophyte, in

the interior of which may be observed a vesicle that soon becomes organised into numerous cells, which constitute the vitelline mass exactly as in the last case. But, arrived at this point, the vitelline mass becomes tuberculated, assuming the appearance of a raspberry, and, instead of a single vitellus, it is found to be an agglomeration of several, each of which contains in its interior a Purkingean vesicle from which a young individual is produced, which is of a totally different form from its parent and covered with cilia, by the aid of which it swims freely about in search of a locality where to fix itself. This form of reproduction will, however, be more particularly noticed in describing the Sertularian Polypes.

Fifth mode, by free gemmation and ova combined. — This last form of the reproductive process is merely a combination of two of the preceding, propagation being effected by the development of a free gemma, in the interior of which there is formed a divided vitellus. In this case a free embryo becomes organised, and takes the form of a young Medusa, according to the second mode described above, in the interior of which is contained an ovum with a multiple vitellus, from which numerous ciliated embryos are produced, as in the *Sertularia geniculata* hereafter to be noticed.

Tubiporidæ. — The polypary of the Tubi-

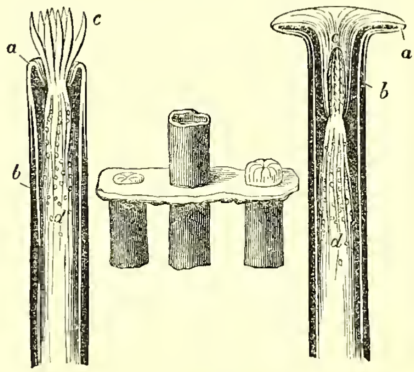
Fig. 52.



Tubipora musica.

pora (*fig.* 52.) consists of several stages of cylindrical tubes placed parallel to each other, or very slightly diverging. These tubes are separated from each other by considerable intervals, but mutually support each other by the interposition of external horizontal plates formed of the same dense substance as themselves, by which they are united together, so that a mass of these tubes exhibits an arrangement something like that of the pipes in an organ; whence the trivial name *musica* by which the species is distinguished. From the upper ends of these tubes the polypes are protruded, and being when alive of a bright grass green colour they contrast very beautifully with the rich crimson of the tubes they inhabit. The mouth* of the polype is suspended in the centre of the tube by means of the soft membrane: it is surrounded with eight tentacula, the margins of which are fringed with two or three rows of fleshy papillæ. Beneath the opening of the mouth is the stomachal sacculus, around which arise the eight ovigerous filaments. Those filaments near their origin are loose and floating, but lower down they become connected with the soft membrane (*fig.* 53. 1, 2, *d*), with which the tube is lined,

Fig. 53.



Tubipora musica.

1, 2, longitudinal sections; 3, portion of the polypary, showing the connecting stage.
a, membranous collar, continuous with the tube; *b*, calcareous tube; *c*, tentacles; *d*, ovaries.

throughout its whole length, but gradually diminishing in thickness as they descend. These filaments are equivalent to the ovigerous tubes of the other Anthozoa; but the ova are here developed upon their external surface, to which they are attached by short pedicles.

Extending between the roots of the tentacula of the polype and the margin of the tube is the membrane, which, in the retracted state of the animal, is drawn into the shape of a funnel, the mouth of the funnel being continuous with the extremity of the calcareous tube. The funnel-shaped membrane is in fact a continuation of the calcareous tube, from which it only differs in texture from the circumstance that the latter has become solidified by the interstitial deposition of calcareous matter in its substance, while the former still retains its softness and irritability.

The funnel-shaped membrane does not terminate suddenly upon the calcareous tube; the latter, indeed, is a prolongation and product of it; the calcareous substance is deposited in this gelatinous membrane in the same manner as phosphate of lime is deposited in the bones of very young subjects, changing its soft texture into hard and solid substance. The manner, therefore, in which this tube is formed cannot be compared to the mode of formation of the cells of Serpulæ or the tubes of Mollusca; in the latter it is a secretion of the skin, almost an epidermic product. In polyparies, on the contrary, there is a real change of soft into solid substance, which is effected gradually, but the calcareous matter is not deposited in layers.

* Anatomie du Tubipore musical par Mons. Lamouroux. Zoologie de Quoy et Gaimard, Voyage de l'Uranie.

We do not doubt that all polyparies, whether flexible or calcareous, are formed in a similar manner, the horny matter of one and the calcareous axis of the other being entirely produced by the conversion of soft gelatinous matter into hard substance through the agency of the membrane which always invests the polypes. Moreover, this infundibular membrane must offer a thousand modifications of form in different families, genera, and even species. Sometimes it is very extensive and irritable; at others, adhering to the parietes of the cells throughout their entire length; the polype is immovably fixed at the opening of its tube. We consider this membrane as one of the most essential organs for the production of the polypary, having observed it in Flustræ, Sertulariæ; and, as far as we know, the same is the case in Madreporigenous polypes.

When the calcareous tube has grown to a certain height, the animal proceeds to form the external horizontal stage, by means of which it becomes united to the tubes in its vicinity. In order to effect this the soft infundibular membrane spreads itself out horizontally, so as to form by its duplicature a kind of rim round the margin of the tube (*fig.* 2, *a*); in this state it loses the irritability that it previously possessed, and its two opposed surfaces becoming united to each other, it is gradually solidified by the deposition of calcareous matter in its substance, so as to form a firm horizontal plate. It generally happens that several of the neighbouring polypes construct similar horizontal stages at the same time, and precisely upon the same plane, in which case all the stages coalesce at their circumference, and become so intimately conjoined as to form but a single floor, which, when calcified, exhibits no marks whatever of the union which has been thus effected. After the formation of this stage the growth of the tube again proceeds upwards, in the same manner as before, until it arrives at its full height.

It is difficult to say how the ova formed upon the ovigerous filaments make their escape; for, seeing their size, it seems impossible for them to pass out by the mouth; and it seems more probable that it is not until a polype dies that the germs of its progeny leave the tube of their parent, and settling down upon the horizontal stage constructed by the preceding generation commence their development.

When first attached in this position the young Tubipore exhibits not the slightest trace of the future polype, but consists of a simple gelatinous membrane folded upon itself so as to resemble a little turban. This turban-shaped mass gradually elongates itself by its upper part, and, as its development proceeds, produces a polype in its interior, the tube which encloses it remaining soft and flexible above, while it is gradually calcified below. And it may here be remarked, that from the small diameter of the commencement of its tube, it is evident that the animal increases in all its dimensions during its advance to maturity.

Sertularidæ.— The depths of the ocean are inhabited by innumerable zoophytes equally remarkable for the beauty of their appearance and the peculiarity of their structure; these are the Sertulariæ, whose arborescent stems have so much the appearance of vegetable productions that they are still regarded by the uninformed as "sea-weeds." On putting a living specimen of a Sertularia (*fig.* 54)

Fig. 54.

Branch of Sertularia geniculata, magnified, showing cells, polypes, and ovigerous vesicles.

into a jar of its native element, and watching it attentively with the aid of a magnifying glass, its real nature becomes at once apparent, and instead of being of vegetable origin, all the elegant ramifications of which it consists are found to be peopled with numbers of hydriform polypes, all actively employed in catching prey, and apparently ministering to the support of the general community formed by their aggregation.

The stem of a Sertularia consists of a hollow tube, composed of a flexible horny substance, diversely ramified in different species, in the interior of which is enclosed a soft animal substance, which constitutes the living portion of the zoophyte. At regular intervals every branch is studded with little cells, composed of the same horny material as the general stem, in each of which is lodged a Hydra, or at least a polype similar to the Hydra in its general characters, the base of which is continuous with the central living pith that

permeates the stem, which thus seems to be nourished by the hundreds of little polypes that are constantly fishing for food.

At certain periods of the year, besides the polype-bearing cells, other horny receptacles are developed, called the *ovigerous vesicles* (*fig.* 55, *h*), in which the ova are produced.

The ovigerous vesicles are differently disposed according to the species, sometimes arising from the branches of the coralline, at others from the axillæ formed by their subdivisions; their shape likewise is very various, and sometimes they are covered with a little *operculum*, or lid, which closes the orifice of the vase-like vesicle during the maturation of the reproductive gemmules, and at last opens so as to permit their escape. These gemmuliferous urns are, however, deciduous, and fall off after the development of the germs of reproduction is completed.

Such being the general structure of the Sertularidæ, we must now proceed to examine more minutely their intimate organisation. The stem of the Sertularian is composed of two layers, of which the exterior (*fig.* 55, *b*),

Fig. 55.

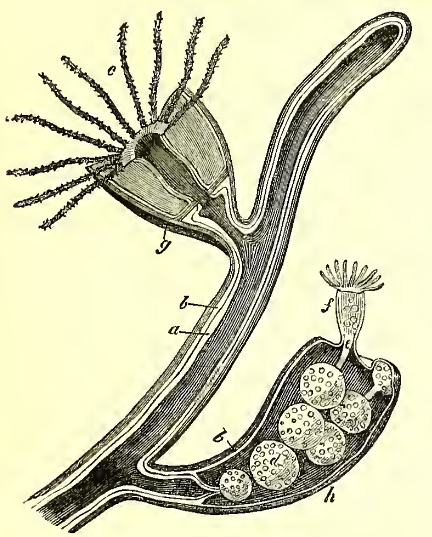


Diagram of Sertularian.

a, inner or nutritive layer; *b*, outer or tegumentary layer; *c*, oral tentacles of the polype; *d*, *e*, gemmules; *f*, polypiform external capsule; *h*, ovigerous cell.

or *tegumentary* layer, is of a dense horny texture, while the internal, or *nutritive* layer (*fig.* 55, *a*), is of a soft pulpy character according to the pattern peculiar to the species; the tegumentary layer expands at appointed distances into the polype-cells (*fig.* 55, *g*); and it is from this layer likewise during the reproductive season that the ovigerous vesicles are developed. The nutritive layer (*fig.* 55, *a*), it will be seen, not only lines the stem, but likewise penetrates into the polype-cells, where it becomes continuous with the body of the contained polype, the structure of which closely resembles that of the Hydra; it seems, in fact, to consist of nothing but a stomachal sacculus, the mouth of which is surrounded with contractile tentacles, which are never, as erroneously stated by some writers, provided with vibratile cilia, such as are possessed by some more highly organised polypes. The nutriment elaborated in the digestive sacculi passes into the central cavity of the stem, in which an evident circulation of globules is apparent, somewhat analogous in its appearance to what is perceivable in the *Chara* and other transparent vegetables.

It is from the nutritive layer which lines the ovigerous vesicles likewise that the reproductive gemmules are developed. These (*fig.* 55, *d*), as they gradually become separated from the nidus in which they are formed, retain their connection with the vital tissue of the nutritive layer, by the intervention of a kind of umbilical cord, until they are sufficiently matured to allow of their escape. When this period arrives each gemmule is found to be covered over with vibratile cilia, by the action of which it detaches itself from the umbilical filament, and, escaping from the reproductive cell, swims away into the surrounding element.

Here, by means of its cilia, it swims about, having much the appearance of a polygastric animalcule, until it finds a fit locality for its development, when it settles down, and, losing its locomotive organs, spreads out like a film of jelly upon the supporting body. The formation of its horny envelope then begins, fibres of which are first extended like the spreading root of a tree, so as to give a firm hold upon the basis for support; and then the stem itself begins to shoot upwards, developing, as it ascends, the nutritive polypes and the horny cells in which they are individually lodged.

In order to understand how growth is accomplished in these tube-clad zoophytes, it will be necessary to refer once more to the preceding diagram (*fig.* 55). The tegumentary layer of the zoophyte (*fig.* 55, *b*) is at first quite soft and expansible, the hard corneous matter by which it is consolidated being afterwards superadded to its texture. Whilst growth is in progress, therefore, this outer layer shoots upwards in conformity with the pattern to which it belongs; but whilst the top of the tube retains its softness and power of growth it is continually fortified below by the deposition of the horny matter which gives it solidity: growth can therefore only proceed at the extremity of every branch where this layer remains capable of further development; for no sooner is it solidified than it remains permanently unchangeable. Hence it is that these zoophytes differ so remarkably from plants in the character of their arborescence: in the latter the stem is increased by constant additions to its thickness, but in the case of the Sertularia no such thickening is possible; so that both stem and branehes retain the same diameter throughout, however much their

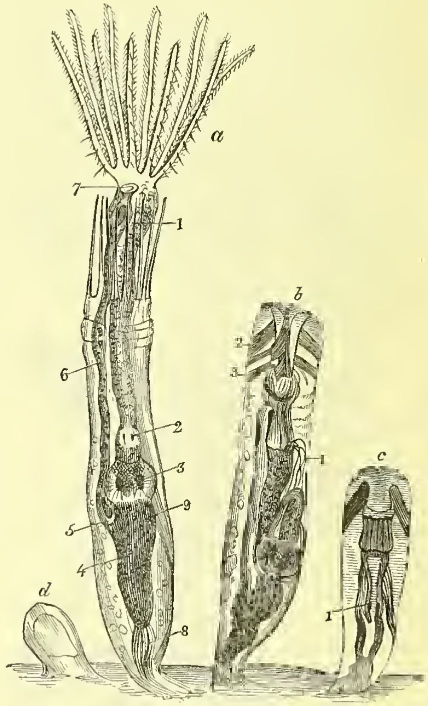
ramifications may be extended. As the growth of the tegumentary layer thus proceeds in one direction only, except when the development of polype-cells calls for its lateral expansion, the nutritive layer within continues to grow *pari passu*, and from it the polypes are produced as the cells become ready to receive them.

BRYOZOA (Ehrenberg), CILIOBRACHIATE POLYPI (Farre). — The Bryozoa, although closely resembling some of the simpler Polypifera, described in the preceding pages, with which, indeed, until a very recent period, they were confounded by zoological writers, differ from them in so many essential points of their structure, that, but for the convenience of description, we should have preferred to regard them as a distinct class, exhibiting a much higher phase of organisation than any of the nudibrachiate races. In all the families of Polypifera we have as yet had occasion to examine, it will have been noticed that the tentacular apparatus around the mouth, although very generally pinnated, are quite devoid of cilia; but in the Bryozoa one of the most obvious circumstances observable in their organisation is, that all the circumoral arms are crowded with vibratile organs, the play of which, when in action, is exceedingly energetic, producing rapid currents in the surrounding water, and thus hurrying towards the mouth of the animal whatever substances may come into the neighbourhood of the vortex so produced, and in this way securing an abundant supply of food, almost without exertion on the part of the creature itself. From this most conspicuous character, common to the entire group, Dr. Arthur Farre was induced to propose for them the name of *Ciliobrachiata*. It is in their internal economy, however, that their chief points of distinction are to be sought. Like the ordinary polypes, most of these little animals inhabit cells of different shapes and various degrees of density. These cells are sometimes calcareous and opaque, but in very many genera so thin and diaphanous that nothing is more easy than to examine, by means of the microscope, the anatomy of the animal within. When thus examined, the differences between a Bryozoon and an ordinary polype become immediately manifest, and may be briefly stated as follows.

In the nudibrachiate polypes the stomach is a simple sacculus unprovided with any intestinal tube or anal orifice, so that after taking food the egesta are necessarily expelled through the oral opening; but in the Ciliobrachiata, not only is the stomach found to be floating loosely in a visceral cavity, and of very complete structure when compared with the digestive sacculus common to the preceding tribes, but it terminates in a complete intestinal canal, provided with a distinct anal orifice, through which the fæces are discharged. Accompanying this advanced condition of the alimentary apparatus all the other systems assume a more elevated type of structure, as will be immediately apparent from the details of their anatomy, upon the consideration of which we are about to enter. Much, doubtless, yet remains to be made out in the economy of these animals; still the researches of Ehrenberg*, Milne Edwards, Audouin†, Thompson‡, Farre§, and Van Beneden‖, have already put us in possession of most important information concerning them, which promises to open a yet wider field for discovery.

The cell of Bowerbankia (*fig.* 56), as de-

Fig. 56.



Bowerbankia densa, magnified 80 *diameters.*

a, one of the animals fully expanded; 1, pharynx; 2, cardia; 3, manducatory organ, or gizzard; 4, stomach, its parietes studded with the hepatic follicles; 5, pylorus; 6, intestine, containing pellets of feculent matter; 7, anus. The gastric (8) and tentacular (9) retractors are seen within the cavity of the body. The flexible portion of the cell, or the operculum, is seen expanded and surrounding the upper part of the body.

b, a similar animal completely retracted. The stomach drawn to the bottom of the cell. The upper portion of the alimentary canal flexed. The tentacula somewhat distorted by the pressure of the operculum. Their retractor filaments (1) relaxed. The upper part of the cell is occupied by the operculum folded up in its axis, and from it the upper (2) and lower (3) sets of opercular retractors are

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* Symbolæ Physicæ.

† Annales des Sciences Naturelles, for Sept. 1828, and July 1836.

‡ Zoological Researches, Mem. V., Cork, 1830.

§ Phil. Trans. for 1837, part 2.

‖ Récherches sur l'Anatomie, la Physiologie et l'Embryogenie des Bryozaires. 4to. Brussels, 1845.

seen radiating, and in their contracted state. These filaments are about $\frac{1}{6500}$ inch diameter in this state.

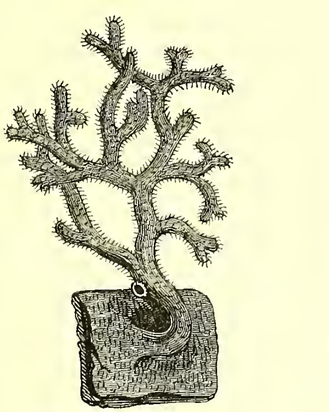
c, An immature animal. The tentacula and alimentary canal rudely formed; the cavity in the latter very distinct. The tentacular and opercular retractors also shown; 1, the gizzard.

d, one of the gemmæ in its earliest state. The cavity just defined, but no animal distinguishable. (*After Farre.*)

scribed by Dr. Arthur Farre, is cylindrical, and closely embraces the body of the animal; it is of a firm unyielding consistence in the lower two-thirds of its extent, but terminates above by a flexible portion, which serves to protect the upper part of the body when the whole is expanded, in which state it is of the same diameter as the rest of the cell; but when the animal retracts, this portion is folded up and drawn in after it, so as to close its mouth. The flexible part consists of two portions, the lower half being a simple continuation of the rest of the cell, the upper consisting of a row of delicate bristle-shaped processes, or setæ, which are arranged parallel with each other round the top of the cell, and are prevented from separating beyond a certain distance by a membrane of excessive tenuity which surrounds and connects the whole. This arrangement is common to all the species possessing a cylindrical cell; but the length of the setæ is very variable; indeed they are sometimes so stunted in their development that their presence is hardly recognisable.

The cells of the *Flustræ* and *Escharæ* are disposed side by side upon the same plane, so as to form a broad leaf-like polypary, which is in the former genus of a coriaceous or horny texture, but in the latter so completely calcified as to resemble the skeletons of the Lithophytous Polypes. The individual cells (*fig.* 59), which are so extremely minute that they

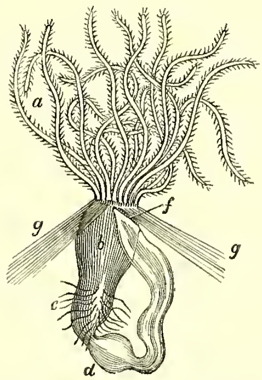
Fig. 57.



Eschara cervicornis, natural size. (*After Milne Edwards.*)

require a microscope for their examination, vary in shape in different species, and generally have their orifices defended by projecting spines, or sometimes by a movable operculum or lid, which answers the same purpose as the setæ of *Bowerbankia*, by closing the entrance during the retracted state of the animal. The growth of these polyparies, which are thus densely populated, is effected by the progressive addition of new cells around the circumference, those occupying the margin being of course the most recently formed, and, indeed, the latter are not unfrequently found inhabited by the living animals, whilst in the older or central ones the original occupants have perished.

Fig. 58.



A polype of Eschara cervicornis highly magnified.

a, tentacula; *b*, first digestive cavity, which seems to be analogous to the respiratory cavity of the compound ascidians; *c*, filaments arising from the part of the alimentary canal immediately below this cavity; *d*, stomach; *e*, intestine; *f*, anus; *g*, retractor muscles. (*After Milne Edwards.*)

The facts observed by Dr. Milne Edwards * relative to the mode of formation of these cells possess a high degree of interest, and materially support the views already given concerning the organised nature of the skeletons of zoophytes in general; proving that the calcareous matter to which their hardness is owing is not a mere exudation from the surface of the animal, but is deposited in the meshes of an organised tegumentary membrane, from which it can be removed with facility by means of extremely dilute muriatic acid. When so treated a brisk effervescence is produced, the cells become flexible, and are easily separated from each other; but they are not altered in form, and evidently consist of a dense and thick membrane, forming a sac, in which the digestive organs of the animal are contained. In this state the opening of the cell has no longer a defined margin, as it seemed to have before; but, as in the case of the *Tubipora musica*, described in a preceding page, the membranous cell is found to be continuous with the tentacular sheath. We see, therefore, that in these creatures the shell is an integrant portion of the animal itself, not a mere calcareous crust moulded upon the surface of its body, being, in fact, a

* Récherches anatomiques, zoologiques, et physiologiques sur les Eschares; An. des Sc. Nat. for 1836.

portion of the tegumentary membrane, which, by the molecular deposit of earthy matter in its tissue, becomes ossified, something like the cartilage of the higher animals, without ceasing to be the seat of nutritive movement. It is evident likewise that what is usually called the body of the Bryozoon constitutes, in fact, but a small portion of it, principally consisting of the digestive apparatus.

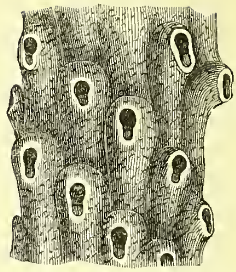
As to the operculum, destined to close the entrance of the tegumentary cell, it is merely a lip-like fold of the skin, the marginal portion of which acquires a dense consistency by interstitial deposit, while at the point where it is continuous with the general envelope it remains sufficiently soft and flexible to form a sort of hinge.

The tegumentary sac, deprived of its carbonate of lime, seems to be formed of a tomentous membrane, covered, especially upon its inner side, with a multitude of cylindrical filaments, disposed perpendicularly to its surface, and closely crowded together. It is in the interstices left by these fibres that the calcareous matter appears to be deposited; for if a transverse section be examined with the microscope the external wall is seen not to be made up of superposed layers, but of cylinders and irregular prisms arranged perpendicularly to the axis of the body.

But the above are not the only arguments adduced by Milne Edwards in proof that these polyparies are maintained in vital connection with the animal. On examining the cells at different ages it is found that after they are completely calcified they undergo material changes of form.

This examination is easily made, seeing that in many species the young sprout from the sides of those first formed, and do not separate from their parents; each skeleton, therefore, presents a long series of generations linked to each other, and in each portion of the series the relative ages of the individuals are indicated by the position which they occupy. It is sufficient, therefore, to compare the cells situated at the base, those of the middle portion, those of the young branches, and those placed at the very extremities of the latter. When examined in this manner it is seen that not only does the general configuration of the cells change with age, but also that these changes are principally produced upon the *external surface*. For instance, in the young cells of *Eschara cervicornis*, the subject of these observations, the walls of which are of a stony hardness, the external surface is much inflated, so that the cells are very distinct and the borders of their apertures prominent; but by the progress of age their appearance changes, their free surface rises so as to extend beyond the level of the borders of the cell, and defaces the deep impressions which marked their respective limits. It results that the cells cease to be distinct, and the polypary presents the appearance of a stony mass, in which the apertures of the cells only are visible.

Fig. 59.



Portion of a branch of the polypary of Eschara cervicornis, magnified 20 *diameters to show the form and arrangement of cells.* (*After Milne Edwards.*)

Muscular system.—The muscular system of Bowerbankia is described as follows.

For the process of retraction two distinct sets of muscles are provided; the one acting upon the *animal*, the other upon the flexible part of the *cell*.

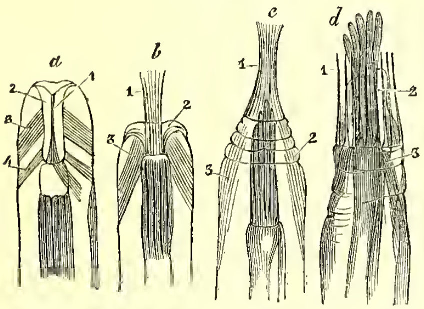
The muscles for the retraction of the animal are contained in the visceral cavity, and consist of two bundles of delicate thread-like chords (*fig.* 56, 8 and 9); the one set, arising from the bottom of the cell, to be inserted about the base of the stomach; the other, also arising from near the bottom of the cell, though generally at the opposite side from the former, and passing up free by the side of the pharynx, to be inserted around the line of junction of this organ with the base of the tentacula. The muscles provided for the retraction of the operculum, or flexible portion of the cell, have their origin from the inner surface and near the top of the stiff part, and are inserted into the flexible portion on which they act. They are most distinctly seen when the flexible operculum is completely drawn in, at which time the latter is folded up so as to occupy the axis of the upper part of the cell, and to it the muscles are seen extending from the opposite sides of the cell from which they have their origin. They consist of six flattened bundles of fibres, having a triradiate arrangement. The upper three sets (*fig.* 60, *a*, 3) act upon the upper part of the cell, and are inserted into it. The lower three (*fig.* 60, *a*, 4) are smaller, and are for the purpose of retracting the bundle of setæ with which it is crowned.

These fasciculi afforded Dr. Farre an excellent opportunity for investigating the structure of this form of muscle. It would appear as if muscular fibre were reduced to its simplest condition. The filaments are totally disconnected, and are arranged the one above the other in a single series. They pass straight and parallel from their origin to their insertion, and have a uniform diameter through their whole course, except that each filament generally presents a small knot upon its centre, which is most apparent when in a state of contraction, at which time the whole filament also is obviously thicker than when relaxed.

The filaments have a watery transparency and smooth surface, and under the highest powers of the microscope present neither an appearance of cross-markings, nor of a linear arrangement of globules. These muscles, though apparently attached to the inner walls of the cell, must yet have the membranous parietes of the body interposed between their insertions and these walls. In the lower part the integument is only occasionally seen separate from the walls of the cell, but above it may be easily discerned in the expanded animal, passing up to be inserted around the tentacular ring, and thus distinctly bounding this part of the body, which is always free within the expanded operculum.

The operation of this mechanism in retracting the animal within its cell is as follows. The tentacula, from being expanded in the form of an inverted cone, are brought together into a straight line, and immediately begin to descend (*fig.* 60, *d*). Their descent is

Fig. 60.



Bowerbankia densa, magnified 80 *diameters. A series to show the mode in which the operculum and upper part of the body is unfolded. The same animal is represented in four different stages.*

a. First stage: the top of the cell completely closed; the setæ folded up in the centre (1), with the flexible portion of the cell (2) inverted and closely surrounding them; the muscles contracted (3, 4.)

b. Second stage: the bundle of the setæ (1) rising from the centre of the cell being forced upward by the pressure of the tentacula; the flexible portion (2) rolling from around the setæ, and the muscles (3) put upon the stretch.

c. Third stage: the flexible portion (2) completely everted; the setæ (1) still lying together; the tentacles just appearing between them.

d. Fourth stage: the tentacula appearing above the margin of the operculum; the integument of the body, which forms the tentacular sheath, half everted (3); the operculum completely expanded. (These stages are taken arbitrarily, the process being continuous.) The animal is shown completely extended at fig. 56, *a.* (*After Farre.*)

effected by the contraction of the muscle (*fig.* 56. 9) which passes from the base of the cell to the tentacular ring, whilst at the same time the stomach is drawn down by *its* retractor (*fig.* 56. 8). The whole body, however, does not descend in a mass, but must be folded up in a somewhat complicated manner, in order that the cell may completely enclose it. For this purpose the œsophagus surmounted by the tentacula descends first, whilst the integument of the upper part of the body begins to be *inverted* at the point where it has its insertion around the tentacular ring. As the descent of the tentacula proceeds, the inversion of the integument continues forming a sheath around them (*fig.* 60, *c*), until the extremities of the arms have descended to a level with the top of the unyielding portion of the cell. The animal is now drawn completely in, the stomach brought close to the bottom of the cell, and the œsophagus bent in the form of the letter S; the tentacula lying straight in the axis of the cell, enclosed in their tegumentary sheath, and so separated from the fluid in the general visceral cavity, the centre of which they have the appearance of occupying, while in fact they are external to it. The *animal* being thus retracted, the next step of the process is to draw in the *upper part of the cell* after it. This process, however, always commences before the retraction of the body is completed, and by the time that the ends of the arms are on a level with the base of the setæ, the latter are brought together in a bundle, and begin to descend apparently by the action of the lower of the two sets of opercular retractors above described. Their descent, like that of the tentacles, takes place exactly in the axis of the upper part of the cell, and is accompanied by an inversion around them of its flexible portion, similar to that of the integument of the body around the tentacula during *their* descent (*fig.* 60, *b*). Whilst the lower set of muscles are drawing down the *setæ*, the upper set complete the retraction of the flexible part, and the whole operculum is thus packed closely in the upper part of the cell, the end of which now presents a triangular indentation, corresponding with the triangular arrangement of the opercular retractors (*fig.* 60, *a*). Thus the whole process of *retraction* may be easily accounted for, and the office of each set of muscles satisfactorily explained; but the protrusion of the animal is effected by a totally different mechanism, viz., by the action of a set of transverse muscles acting upon the lining membrane of the cell, so as by their contraction to diminish considerably the *diameter* of the visceral cavity, and consequently exercise a pressure upon the fluid which it contains. The effect of this will be to elongate the body in the direction in which it is most free to move; but Dr. Farre supposes that the act of protrusion is materially assisted by the cooperation of the alimentary canal, which undoubtedly has the power of straightening itself from the sigmoid flexure into which it is thrown when the animal is retracted; and that this is the case appears the more probable, when we reflect that in the case of the simple hydriform polypes the advance and receding of the animal in its cell is entirely effected by the action of the parietes of the body, which are analogous to the alimentary canal in the present case, the hydriform po-

lypes possessing no distinct muscles to assist in these operations.

In some species of Bryozoa there are only two sets of opercular muscles, whilst in others one set only is perceptible.

Alimentary system. — In Bowerbankia the whole alimentary apparatus has been minutely described and figured by Dr. Farre.* The tentacula are united together at their base to form a circle, in the centre of which is the mouth, and from which descends the œsophagus, bulging a little at its commencement, and then contracting and passing down nearly straight to its termination. The parietes of the œsophagus, especially at the upper part, which may be more correctly denominated the pharynx (*fig.* 56, *a*, 1), are thickly studded with minute oval spots, arranged closely in contact with each other. The whole organ appears to be highly irritable, and contracts vigorously when food is introduced into it.

At the termination of the œsophagus is a small distinct cardiac orifice (*fig.* 56, *a*, 2) opening into a small globular cavity (3), of singular construction, that appears to perform the office of a gizzard, the parietes of which are thicker than any other part of the alimentary canal. This gizzard contains two dark round bodies, placed opposite to each other, from each of which dark lines are seen radiating. In the space between these two dark bodies may be seen a number of squamiform spots, arranged closely in contact, and presenting a beautifully regular tesselated appearance, which, on minute examination, is found to consist of a pavement of gastric teeth.

The gizzard opens downwards into the true digestive stomach (4), an oblong cavity terminating below in a blunt extremity. The entire walls of the stomach are thickly studded with spots of a rich brown colour. These appear to be hepatic follicles, and to prepare a fluid that tinges the whole organ, as well as its contents, of a rich brown hue.

From the upper part of the stomach, and by the side of the entrance from the gizzard, arises the intestine (6) by a distinct pyloric orifice (5) that is surrounded by vibrating cilia. The intestine is narrow, and passes up straight by the side of the œsophagus, from which it is entirely separate and free, and terminates by a distinct anal orifice in the delicate parietes of the body, close to the outer side of the tentacular ring. The parietes of the intestine are marked with pale spots, and, like those of the whole of the alimentary canal, possess a high retractile power. The animal, when in full vigour, is seen projecting from its cell with the arms extended and the cilia in active operation, the upper part of the body being frequently turned from side to side over the edge of the cell, the extremity of which, from its peculiar flexibility, moves with it. The particles carried to the mouth by the action of the cilia, after remaining a little while in the pharynx, are swallowed by a vigorous contraction of its parietes, and carried rapidly down the œsophagus and through the cardia into the gizzard, which expands to receive them. Here they are submitted to a kind of crushing process, the parietes of the organ contracting firmly upon them, and the two dark bodies being brought into apposition. Their residence, however, in this cavity is only momentary, and they are immediately propelled into the true stomach below, where they become mixed with its contents, which, during digestion, are always of a rich brown colour, being tinged with the secretion of its parietal follicles.

The food appears to be retained for a considerable time in the stomach, and may be seen to be frequently regurgitated into the gizzard, whence, after having been again submitted to its operations, it is returned to the stomach. Here it is rolled about by the contractions of its parietes, and at its upper part is frequently submitted to a rotating motion. This rotation of particles is chiefly near the pyloric orifice, and a mass may be often seen projecting through the pylorus into the intestine, and rotating rapidly in the direction of the axis of the orifice. This rotation is effected by the action of cilia surrounding the pyloric orifice, which, in very transparent specimens, are distinctly visible with high powers of the microscope.

The granular matter, after rotating for some time at the pylorus (a provision for preventing its too rapid escape from the stomach), passes into the intestine, where it accumulates in little pellets that distend the parietes of the tube, and it is possible that it may here be still further acted upon by these parietes which have a spotted appearance.

By the contraction of the intestine the little pellets of excrementitious matter are carried rapidly upwards to the anal orifice, which is seen to open and the little pellet to be tilted over its edge, when it is immediately whirled away from the sight in the current produced by the ciliated tentacles, and the orifice of the tube again contracts.

The general character of the alimentary canal appears to be similar in all the ciliobrachiate polypes, but in many genera the gizzard does not exist.

The anatomy of the animals inhabiting the cells of *Flustræ* and *Escharæ* differs in some particulars from that of *Bowerbankia.* In these, the crown of ciliated tentacula is inserted into the extremity of a kind of proboscis, which is itself enclosed in a cylindrical retractile sheath. From the margin of the opening of the cell arises a membrane equalling in length the contracted tentacles, and serving to enclose them when the animal retires into its abode. The tentacula when thus retracted, as was the case in *Bowerbankia*, are not bent upon themselves, but are perfectly straight and united into a fasciculus, the length of which, however, is much less than that of the same organs when expanded.

* Loc. cit.

By the opposite extremity to that which is derived from the margin of the cell, the tentacular sheath unites with a tolerably capacious tube, the walls of which are exceedingly soft and delicate, and near the point of their union we may perceive a fasciculus of fibres running downwards to be inserted upon the lateral walls of the cell. These fibres appear to be striated transversely, and are evidently muscular; their use cannot be doubted. When the animal wishes to expand itself, the membranous sheath above referred to becomes rolled outward, everting itself like the finger of a glove as the tentacles advance. The muscular fasciculi are thus placed between the everted sheath and the alimentary canal, and by their contraction they must necessarily retract the whole within the cell.

The first portion of the alimentary canal (*fig.* 58, *b*) is inflated, and much wider than the rest; it forms a kind of chamber, in which the water set in motion by the cilia of the tentacles appears to circulate freely. The walls of this chamber are exceedingly delicate; the soft membrane forming them is puckered, and appears traversed by many longitudinal canals united by minute transverse vessels; this appearance, however, may be deceptive.

Beneath the first enlargement, the digestive apparatus becomes narrower, but immediately expands again, and offers at this point a certain number of filiform appendages (*c*), which appear to be free and floating in the interior of the cell. To the second cavity succeeds a narrow canal opening into a third dilatation, generally of a spherical form (*d*). From the last-named viscus issues a kind of intestine, which soon bends upon itself and becomes attached to an organ of a soft and membranous texture, having the appearance of a cæcum, and which seems to be continuous superiorly with the digestive tube. The latter continues its progress towards the upper part of the cell, and ultimately terminates by a distinct anal aperture upon the upper aspect of the tentacular sheath. The operculum which closes the cell in Flustræ and Escharæ is moved by two muscular fasciculi inserted into the internal face of this valve by the intermedium of two filaments analogous to tendons; by their inferior extremity these muscles are attached to the walls of the cell, and when, by its own elasticity, the operculum is turned back, and the mouth of the cell thus opened, they by their contraction can close it like a door.

Reproduction. — The first mode of reproduction observed in the Ciliobrachiate polypes is by a process of gemmation from the common stock or creeping stem upon which the animals grow. This is easily witnessed, as the gemmæ are met with in every progressive stage of development upon the same specimen, as represented in *fig.* 65.

The smallest gemmæ are described by Dr. Farre as homogeneous in their texture, forming little nodules on the parent stem. Those further advanced were seen to present something like a boundary line, indicating the thickness of the parietes of the future cell. Within this, in others, was a dark mass, which in larger ones presented a rough outline of the form of the complete animal. Those about half grown had all the parts distinctly traced out; the retractor muscles completely formed; the tentacles short and clumsy; the walls of the alimentary canal thick, and its boundaries clearly defined.

This mode of propagation has been still more completely studied by Professor Van Beneden, whose opportunities of observation enabled him to prosecute the inquiry more closely.

In *Pedicellina* the phenomena attending the gemmiparous mode of reproduction are described by Professor Van Beneden as presenting the following phases of development. First, there sprouts from the common stem of the Bryozoon, without any determinate situation, a tubercle which is but a prolongation from the stem itself (*fig.* 65, *a*, 8); this tubercle extends outwards, becomes more prominent, and soon swells out into a vesicle (*b*, 8), which is the first appearance of the new individual. Up to this period the interior of this vesicle, is like that of the stem itself, of which it is only an extension; but now a cellule becomes visible in its centre, which forms the point of departure whence the development of the embryo proceeds.

Around this primitive cell a series of other very small cellules soon group themselves, which seem to constitute the parietes of the primitive vesicle or the blastoderm, the original cell representing the vitelline cavity. The bud enlarges, and as its growth proceeds the internal tissue becomes thickened, so as to fill it; subsequently an indentation is apparent on each side of the little cavity which separates it into two halves, the inferior of which will form the stomach, properly so called, while the upper division will become the anterior space between the tentacula.

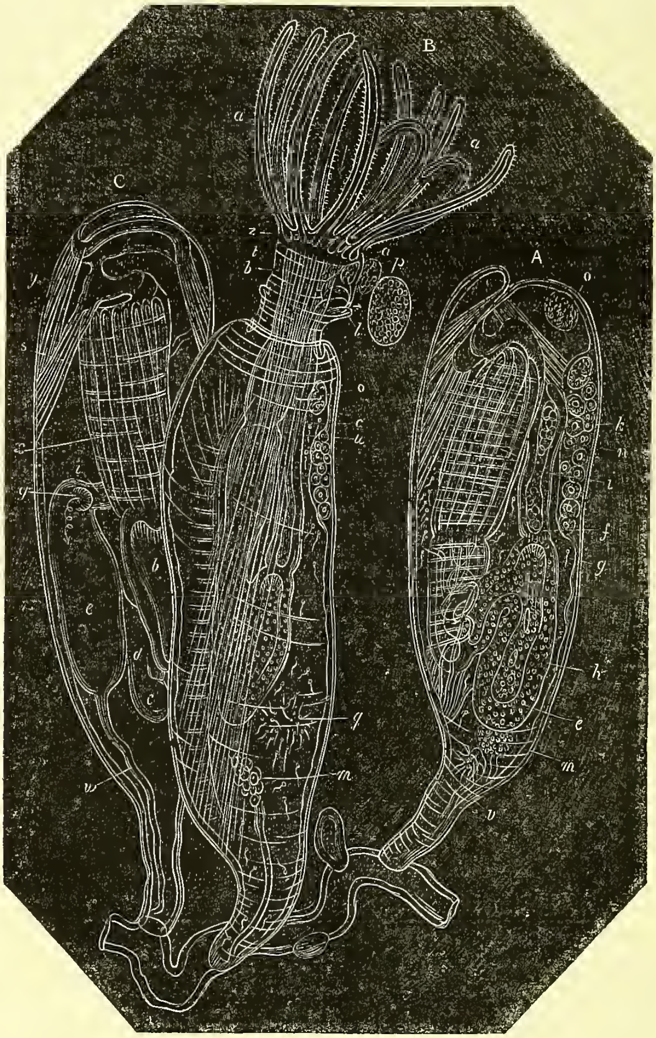
The mode of reproduction by gemmæ has been carefully studied in the genus *Laguncula* (*Lagenella* of Farre) by the same investigator. The reproductive buds sprout from the creeping stems (*fig.* 61, γ) which connect the individual animals, appearing at first as a slight prominence, that soon expands into a rounded tubercle, which is the commencement of a new cell.

On close inspection, this bud is found to consist of a transparent envelope, which is, in fact, a continuation of the general investment of the polype. This rudimentary cell is lined throughout with a soft membrane, having its inner surface studded with minute globules, by the accumulation of which the polype is ultimately formed. The bud itself is hollow, and communicates with the parent stem. It therefore has nothing in its composition resembling that of an egg; neither distinct vesicle nor vitellus; this condition of the gemma is represented in *fig.* 62. 1. The new-formed cell soon grows taller, and its lining membrane becomes thicker, and indicates the commencement of the intestinal canal, which is at first a simple cavity, bounded by the

thickened lining membrane of the cell. This cavity once formed, the development of the different organs proceeds rapidly. First, in the middle of the cavity there appears a longitudinal fold resembling two lips (*fig.* 62. 2), which, as they approach each other, divide the cavity of the body into an anterior and a posterior compartment. The two lips, which have a valvular appearance, become indented very regularly along their margins, and are soon recognisable as the rudiments of the tentacular circle (*fig.* 62. 3).

At this epoch, it must be remarked, the polype presents two cavities distinct from each other. There is a space between the walls of the body and the parietes of the

Fig. 61.



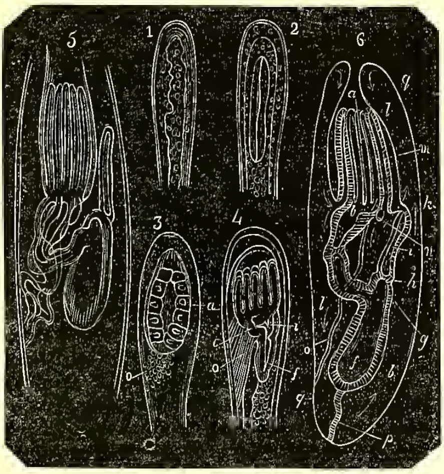
Laguncula repens, magnified 400 *diameters.*

A. The animal completely retracted into its cell; B, another individual completely expanded; C, the outlines of another individual retracted. The same letters apply to each of the figures. The various viscera are situated in different planes, but are here represented all in the same.

a, the tentacles, protruded and expanded in B.; the arrow indicates the set of the currents caused by the vibration of the cilia; *b*, buccal cavity; *c*, valve separating this cavity from the œsophagus; *d*, œsophagus; *f*, pyloric valve; *g*, cilia, producing the rotation of the food in the stomach; *h*, thickness of the parietes of the stomach; *i*, intestine; *k*, excrement contained in its interior; *l*, anus; *m*, testicle; *n*, ovary; *o*, ovum escaped from the ovary; *p*, apertures through which the eggs are expelled, with an ovum in the act of escaping, *q*, spermatozoa, freed from the testicle, and floating in the fluid that surrounds the digestive canal; *r*, *s*, *t*, *u*, *v*, muscles, retractors of the parts to which they are attached; *w*, principal retractor muscle; *x*, transverse folds of the collar; *y*, bands, perhaps muscular, of the collar; *α*, nervous œsophageal ganglion; *β*, stalk; *γ*, a young bud. (*After Van Beneden.*)

future alimentary canal, the interspace being in communication with the stem of the parent polype, and filled with a fluid that is analogous to the blood of the higher animals; superiorly this cavity likewise penetrates into the tentacles, and the fluid which bathes the exterior of the alimentary canal thus finds admission even to the extremities of those organs (*fig.* 62. 6, *m*).

Fig. 62.



Development by buds of Laguncula repens.

1. A young bud, with the cavity of the stalk extending into it, the parietes thickened at one part; it is from this part that the intestinal canal and tentacles are formed.

2. A sac is formed in the interior, having a longitudinal fold, which afterwards becomes the tentacles.

3. The rudiments of the tentacles are here apparent: the view is taken so that the space which they surround is visible.

4. In this figure all the organs of the animal can be distinguished, but the bud is not yet opened.

5. Here the cell is opened, and the animal is ready to expand itself.

6. Section of the adult animal; *a*, tentacles; *b*, mouth; *c*, buccal cavity; *d*, valve separating this cavity from the œsophagus; *e*, œsophagus; *f*, stomach; *g*, pyloric cilia; *h*, pyloric valve; *i*, intestine; *k*, anus; *l*, peri-intestinal cavity; *m*, communication of this cavity with the interior of the tentacles; *n*, nervous ganglion; *o*, long retractor muscle; *p*, retractor of the stomach; *q*, walls of the cell. (*After Van Beneden.*)

The second cavity, which is the intestinal, has as yet no communication with the external world. As the formation of the tentacula proceeds, the portion which is situated in front of them will become the sheath, and the other part the proper intestinal canal; the former cavity is, therefore, in all respects comparable to that which exists in the Tunicata situated in front of the proper oral orifice and lined with the branchial vessels. The tentacles of these polypes, in fact, if connected by transverse canals and attached to the sheath, would transform the animals in this phasis of their growth into Ascidians.

As the tentacula are formed by the prolongation of the tubercles which were their first rudiments, the cavity of the stomach and the rest of the intestinal tube gradually become apparent, and at the same time some globules are visible disposed around the cul-de-sac of the former viscus, which gradually become arranged into fibrillæ, and constitute the retractor muscles.

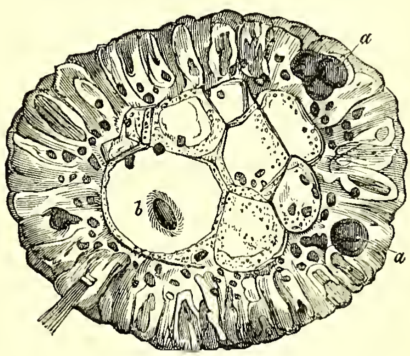
At what time the nervous system is formed could not be detected.

When the cell has nearly reached its full development, the tentacular sheath is completed in the same proportion, the parietes of the cell become softened, and an opening is formed which brings the young polype into communication with the surrounding element. The Bryozoon has now attained its full development, and can expand its tentacula, but as yet there are no traces of the reproductive organs, which seem to be formed after all the others.

In *Halodactylus* reproduction by gemmation is effected by the development of young animals and cells amongst the mature ones. The newly formed cells are triangular, and the animal looks like a mere spot in their centre. As they grow they thrust aside the surrounding cells, and the number of their sides increases until they acquire the regular hexagonal form of the adult.

The *Halodactylus* likewise afforded Dr. Farre an opportunity of witnessing the second mode of reproduction common to the Bryozoa, namely, by the development of ciliated gemmules. These are readily seen in Spring as minute whitish points situated just below the surface of the mass (*fig.* 64, *a*). Sometimes

Fig. 63.



Thin transverse section of Halodactylus diaphonus. The centre occupied by cellular tissue and water. The circumference formed by cells in close apposition. The brown bodies scattered through the substance.

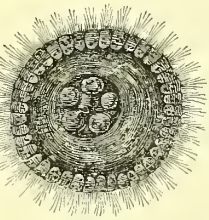
a, *a*, position of the gemmules, enclosed in the sac; *b*, one of the gemmules escaped during the section into the central tissue. (*After Farre.*)

they are of a darker colour, and exceedingly numerous, appearing to occupy almost its whole substance. If one of these points be carefully turned out with a needle, it is found

to consist of a transparent sac, in which are contained generally from four to six of the gemmules, which, as soon as the sac is torn, escape, and swim about with the greatest activity, affording a most interesting subject for microscopic investigation.

When viewed with a power of 40, linear measure, they are seen to be of an oval or rounded form (*fig.* 63, *b*), convex above and

Fig. 64.



Halodactylus diaphanus, a gemmule seen from above; the cilia as when slowly acting round the margin in waves. (*After Farre.*)

nearly plane below, and fringed at the margin with a single row of cilia, which appear to vibrate in succession around the whole circumference.

Under an amplification of 120 they assume a different aspect (*fig.* 64), and their minute structure is clearly discerned. Viewed as opaque objects, both the body and cilia have a silvery whiteness, but by transmitted light the former appears of a dark brown, and the cilia of a golden yellow colour. Upon the most convex part of the body, which is not generally in the centre, but leaning to one side, are set from three to five transparent bosses, surrounded by a circle, and other circles are seen extending to the base of the body, which is bounded by a row of prominent tubercles. These marginal tubercles are from thirty to forty in number; and from the circumstance of the cilia arising from them, Dr. Farre considers it probable that they are for the purpose of governing their motions, and therefore analogous to the muscular lobes of *Hydatina senta* and other *Rotifera* figured by Ehrenberg. No structure, however, could be detected in these, nor in any other part of the body, beyond a mere granular parenchyma. When thus highly magnified, it is seen that what examined with a lower power appeared to be a single cilium is, in fact, a wave of cilia, and that their motion, instead of being in the direction of the circumference of the disc, is at right angles to it. The ciliary phenomena are the most readily observed when the gemmule is nearly at rest, or has become languid; it then lies either with the convex or the concave side uppermost, and with the cilia, which are of great length, doubled in the middle upon themselves, so that their extremities are brought back nearly to touch the margin of the disc from which they arise. The whole fringe of cilia is then suddenly unfolded, and after waving up and down with a fanning motion, they are either again folded up towards the under surface of the body, or they commence their peculiar action.

As the cilia have the appearance of moving in waves round the disc (*fig.* 64), each wave may be thus analysed. From a dozen to twenty cilia are concerned in the production of each apparent wave, the highest point of which is formed by a cilium extended to its full length, and the lowest point between every two waves by one folded down completely upon itself, the intervening space being completed by others in every degree of extension, so as to present something of the outline of a cone.

As, however, the persistence of each cilium in any one of these positions is only of the shortest possible duration, and each takes up in regular succession the action of the adjoining one, so that cilium, which by being completely folded up formed the lowest between any two waves, now in its turn, by its complete extension, forms the highest point of a wave; and thus, while the cilia are alternately bending and unbending themselves each in regular succession after the other, the waves only travel onwards, whilst the cilia never change their position in this direction, having, in fact, no lateral motion. When the waves travel very rapidly, they appear smooth on one side and fringed on the other. The whole of the ciliary motions are so evidently under the control of the animal, as to leave no doubt on this point. The whole fringe of cilia may be instantly set in motion, and as instantaneously stopped, and their action regulated to every degree of rapidity. Sometimes one or two only of the waves are seen continuing their action, while the remainder are at rest, or isolated cilia may be observed slowly bending and unbending themselves, or projecting entirely at rest. The body is generally pointed towards one extremity of the oval, and at this part may be observed a bundle of cilia longer than the rest, and moving very rapidly. Their vibrations were in several instances counted very evenly at 230 a minute, continuing in action when all the others were folded up. These Dr. Farre thinks may be respiratory whilst the others are chiefly locomotive. Dr. Farre thinks there can be little doubt that this explanation of the action of the cilia in the gemmules is applicable likewise to those of the tentacula of the adult animal, and not only in the *Hylodactylus*, but throughout the class generally; for he observed that the tentacular cilia are infinitely more numerous when at rest than they appear to be when in motion, and also that they vibrate, not in the direction of the plane of the arms, but at right angles to it, and with the same hook-like form as in the gemmules. In this way the apparent travelling of the cilia up one side of the arm and down the other, as the eye is seduced to follow the waves which they seem to produce, is at once explained.

It would be impossible to account for the

variety of motions which the gemmules are capable of executing, were it not obvious how complete is their control over the action of the cilia, which are their sole locomotive organs. They generally swim with the convex part forwards, and with the greatest rapidity. Sometimes they simply rotate upon their axis or they tumble over and over, or, selecting a fixed point, they whirl round it in rapid circles, carrying every loose particle after them. Others creep along the bottom of the watch-glass upon one end with a waddling gait; but generally, after a few hours, all motion ceases, and they are found to have attached themselves to the bottom of the glass. At the expiration of forty-eight hours the rudiments of a cell were observed extending beyond the margin of the body, but at this stage the animals invariably perished, and Dr. Farre had no opportunity of witnessing their further metamorphosis.*

Reproduction by ova. — In the genus *Pedicellina* Van Beneden discovered in most of the individuals he examined, situated immediately above the stomach, some rounded opaque corpuscles of a lactescent appearance (*fig.* 65, *k*), which seem to be attached to that viscus; this he considers to be the ovary, containing ova in various stages of development. In the same situation he perceived an organ that he

* Phil. Trans. 1837, p. 410.

Fig. 65.

Pedicellina Belgica.

A. Section. B. A group of individuals in various states. The letters refer to each of the polypes. *a*, mouth; *b*, œsophagus; *c*, stomach; *d*, pylorus; *e*, intestine; *f*, anus; *g*, tentacular sheath; *h*, tentacles; *i*, oral disc; *k*, ovum in the ovary; *l*, parietes of the polypary; *m*, stalk; *n*, superior, and *o*, inferior, enlargement; *p*, muscles of the stalk; *q*, intermuscular cellules? 1. An adult individual retracted into its cell, showing the muscular fasciculi; *r*, sphincter; *s*, retractor; *t*, oblique; *u*, *v*, animalcules accidentally attached to the stalk; 2, 3, 4, polypes in the act of expanding; 5, 6, 7, young individuals; 8, buds in different stages of development; *a*, 8, very rudimentary; *b*, 8, showing the cellule; *c*, 8, *d*, 8, a little more advanced; *e*, 8, the embryo visible; 9, the connecting stalk; 10, an enlargement giving rise to several buds; 11, tentacle magnified; 12, a little group of the natural size. (*After Van Beneden.*)

looks upon as being the testis, his opinion being founded on the fact that when a mature specimen of the animal is placed between two plates of glass, and gently compressed so as to rupture its parietes and cause the escape of the viscera, spermatozoa are discoverable in the one and ova in the other. The spermatozoa exhibit considerable vivacity in their movements, have a disc-like body and a caudal filament, and are proportionately of large size; around them may be seen multitudes of free cellules without caudal appendages, which are apparently young spermatozoa.

In some individuals the spermatozoa are so numerous that the intestinal canal appears completely enveloped by them, and the whole peri-intestinal cavity seems alive with their movements.

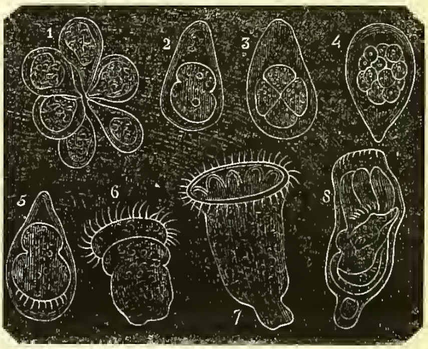
In the mature ovary ova are discoverable in different degrees of development, in each of which the vesicles of Wagner and of Purkinje are, according to Professor Van Beneden, distinctly visible. In those ova which approach their complete maturity an external vitelline membrane, or chorion, and a vitellus are perceptible, but the two vesicles above mentioned have disappeared.

When arrived at the proper term the ova break from their envelope, or ovisac, and fall into the general cavity of the body, where they move freely about surrounded on all sides by spermatozoa. At length the eggs accumulate in the interior of the body, near the base of the tentacula, and their escape, as witnessed by Van Beneden in Laguncula repens, is at length accomplished in the following manner. An egg presents itself at an orifice, situated in the vicinity of the anus, through which its external membrane partially protrudes, constituting a sort of hernia (*fig.* 61, *p*). The vitellus gradually flows from the still enclosed portion of the egg into that which is external, and when the vitellus has thus entirely passed out, the egg is found separated from the parent animal and falls into the surrounding water. These eggs are entirely destitute of external cilia, and are carried off by any casual current to attach themselves where chance may bring them; they are also remarkable for the irregularity of their shape, some being completely angular, their form seeming to depend upon the pressure they have been subjected to in the interior of their parent.

Development by ova. — In *Pedicellina* Professor Van Beneden has witnessed the escape of upwards of twenty eggs from a single individual. They are of a pyriform figure, and enclosed in a pellucid membrane, by the intervention of which they adhere together (*fig.* 66. 1), so that in the interior of the body of the parent Bryozoon they have a racemose appearance, and when extended spontaneously they are generally united together in pairs. Between the vitellus and the envelope of the egg there is always a small quantity of a transparent whitish fluid, which doubtless represents the albumen, while the pellucid external membrane itself is the chorion.

The vitellus breaks up into granules, at first of large size, and afterwards by subdivision of smaller and smaller dimensions, giving a tuberculated appearance like that of a raspberry to the mass. This division seems to be accomplished exactly as in the ova of the higher animals, the yolk first separating into two (*fig.* 66. 3), then into four (*fig.* 66. 2), after which its breaking up proceeds rapidly (*fig.* 65. 4).

Fig. 66.



A series illustrating the development by ova of Pedicellina. (*After Van Beneden.*)

The embryo enclosed within the egg soon assumes a rounded form and speedily appears divided by two indentations near its middle (*fig.* 66. 5), by which it is separated into an anterior and a posterior moiety, and vibratile cilia become apparent upon the anterior extremity.

That portion where the cilia have become apparent insensibly enlarges and assumes the shape of a funnel (*fig.* 66. 6), while the long cilia by which it is fringed begin to keep the particles suspended in the water around them in rapid motion. The margins of the funnel gradually extend themselves (*fig.* 66. 7), the body exhibits frequent contractions, and at the end of about two hours little tubercles become apparent upon its anterior extremity, which subsequently become developed into the tentacula. Professor Van Beneden thinks that the original cilia disappear when the tentacula have become developed and furnished with their proper vibratile apparatus. The formation of the tentacula at once indicates which are the two extremities of the body and the point by which the embryo will subsequently attach itself.

The embryo when mature is quite at liberty and strikingly resembles some forms of Infusoria, but after a little while a pedicle is formed, whereby it proceeds to fix itself to some foreign body, and thus permanently assume the aspect of its race (*fig.* 66. 8). The pedicle seems to be formed by a cell developed below the stomach, which grows directly outwards, and thus completes the organisation of the young Bryozoon.

(*T. Rymer Jones.*)

POPLITEAL REGION, and POPLITEAL ARTERY. — The term Popliteal Region is applied to that portion of the

lower extremity which occupies the bend of the knee, and includes also the posterior surface of the thigh, as high as the junction of its middle and lower thirds, and the back part of the upper fourth of the leg : — by its muscular boundaries this region is distinctly defined, and is of a diamond shape, but it is by no means so accurately limited when examined with reference to its surface. The external form of the popliteal region differs materially in the flexed and extended position of the leg; in the latter ease, it has somewhat of an oval outline, the longest diameter, which is in the vertical direction, greatly exceeding the transverse: the greatest transverse breadth is at the bend of the knee-joint. The surface presents an elongated rounded projection, which is received above between two narrow ridges diverging from each other as they are traced downwards; these latter are produced by the stretching of the skin over the tendons of the hamstring muscles, and are rendered still more distinct by a more or less deep groove, which separates them on either side from the general convexity of the region; inferiorly, the convexity of the surface passes off insensibly to the calf of the leg: these characters are more marked in the strong and muscular. When the leg is bent upon the thigh, the roundness of the upper part of the region is lost, and gives place to more or less of a depression or pit between the still projecting ridges produced by the hamstring museles; this depression is popularly known as the hollow of the ham.

The popliteal region is scooped out into a deep, narrow, diamond-shaped cavity, to which in the following description the term "popliteal space" will be applied; it is situated between the diverging hamstring muscles and the converging heads of the gastrocnemius, and is broader above the knee-joint than below; it is filled up by a considerable quantity of fat with areolar tissue, and traversed by the popliteal vessels and nerves; the semitendinosus and semimembranosus muscles on the inner side, and the biceps flexor cruris on the outer, bound this space laterally and above; the two heads of the gastrocnemius with the plantaris muscle form its lateral boundaries below; anteriorly it is bounded by the posterior surface of the femur, the knee-joint or rather its posterior ligament, and the popliteus muscle, and is closed in posteriorly or superficially by a strong fascia and the skin: it may be as well to mention, that in dissecting the popliteal space we are looking at it from behind, so that the term superficial relates to its posterior aspect. Before describing the contents of the space, it will be necessary to consider more at length the structures which constitute its boundaries.

The skin and subcutaneous areolar tissue present no very remarkable features for examination; the former is marked at the bend of the joint by a few transverse furrows, which are obliterated when the leg is fully extended; it is smooth and adherent to the subjacent tissue. This latter differs in no respect from the same structure elsewhere; it eontains a variable amount of fat, and is traversed above by a few filaments from the posterior cutaneous nerve of the thigh, and below, though not invariably, by the posterior saphena vein. This superficial vessel begins, by small branches, at the outer side of the foot, passes behind the outer malleolus, and erosses obliquely to the middle line of the leg, then ascends vertically upon the aponeurosis, which it frequently perforates before reaching the popliteal region, passes into the space between the heads of the gastrocnemius to terminate in the popliteal vein; it occasionally sends upwards a branch upon the fascia lata, which, winding round the inner side of the thigh, joins the saphena major vein. The communicans tibialis nerve courses with this vein, which it elosely accompanies at the lower part of the leg, but is separated from it in the popliteal region by being buried between the heads of the gastrocnemius. The posterior saphena vein is liable to become varicose, but less frequently so than the saphena major: this circumstance is of course readily accounted for by the difference of length and size between the two.

The fascia lata, descending from the posterior surface of the thigh, forms the strong aponeurosis which eloses in the popliteal space behind; stretched across this region, it is connected on either side with the condyles of the femur and the tendons of the extensor muscles of the leg, and continued around the joint; it is especially fixed to the outer lip of the linea aspera by a septal process of the fascia lata which dips between the vastus externus and biceps muscles, and on the inner side receives fibres from the tendons of the muscles which pass behind the inner condyle; it approximates the lateral boundaries of the space, gives to it a greater depth, and protects the vessels and nerves by bearing off from them any undue pressure. By its unyielding and dense structure, aneurismal or other swellings are delayed in their approach to the surface, and for the same reason abscesses are prone to burrow and require an early and free opening. This aponeurosis presents numerous transverse fibres, is perforated sometimes by the saphena minor vein, and is adherent by fibrous slips with the subcutaneous areolar tissue; it is continuous below with the aponeurosis of the leg.

The muscles forming the boundaries of the popliteal space will be considered only so far as they relate to it; their more detailed description will be found in the articles MUSCLES OF THE LEG AND THIGH. The semitendinosus muscle, after separating from the biceps, terminates in a long, slender tendon, which descends inwards, lying upon the surfaee of the semimembranosus; then crosses the inner head of the gastrocnemius, and placed between it and the tendon of the semimembranosus, winds round the inner condyle to pass to its insertion. The semimembranosus in descending at first erosses obliquely the popliteal artery, continues membranous and fleshy to the eondyle of the

femur, and is of sufficient breadth, at this its lower part, to extend beyond either side of the tendon of the former muscle, thus contracting the lateral dimensions of the bottom of this space by encroaching within it. The long head of the biceps, leaving the former muscles, descends obliquely to cross the outer origin of the gastrocnemius by its strong tendon, which is subsequently implanted into the head of the fibula; it receives, as it descends, the thick fleshy mass of its shorter portion, which assists the semimembranosus in narrowing the bottom of the popliteal space, shutting it in also externally and above, by its attachment to the linea aspera as low as the outer condyle. The superior angle of this space is formed at the point of divergence of these hamstring muscles, and the lateral angles are occasioned by their crossing the heads of the gastrocnemius; this latter muscle is attached to either condyle of the femur by its two heads, the internal being the longer and larger; they converge to unite in the median line a little below the knee-joint: these origins have each a bursa interposed between them and the condyle; the little fleshy belly of the plantaris muscle accompanies the outer head and lies beneath it; by their union the inferior angle of the popliteal region is produced. At the bottom of the space we meet with, first, the posterior, flat, triangular surface of the femur, and, secondly, the back part of the knee-joint strengthened by its posterior ligament (the ligament of Winslow). This structure is derived from the tendon of the semimembranosus; it insinuates itself beneath the inner head of the gastrocnemius, and, forming a flat and dense tendinous aponeurosis, extends across the back of the joint to the external condyle, adhering to the synovial membrane; there are several small openings in it, produced by a separation of its fibres, for the passage of vessels to the interior of the articulation:—lastly, the popliteus muscle, which is flat, triangular, and situate behind and below the joint, begins, by a round tendon, from the outer condyle and spreads out by muscular fibres upon the posterior surface of the tibia to be inserted into its oblique ridge.

On removing the fascia, two large nerves are seen to traverse the popliteal space, and are indifferently called the internal popliteal or tibial, and the external popliteal or peroneal nerves; they are the terminal branches of the sciatic, which nerve generally bifurcates at the upper angle of this region: the point of division, however, is very variable, sometimes occurring even within the cavity of the pelvis, in which case, as the two nerves emerge, they are usually separated by a slip of the pyriformis muscle; commonly a very trifling dissection will affect their separation some distance up the thigh. The internal popliteal or tibial nerve is the larger of the two, and appears to be the continuation of the sciatic; it takes a nearly perpendicular course through the popliteal space in the middle line, and will be found at first to lie almost immediately beneath the fascia, a small quantity of fat intervening; it dips more deeply into the space as it descends, passes between the heads of the gastrocnemius and over the popliteus muscle, and, insinuating itself beneath the tendinous arch of the soleus, courses down the back of the leg under the name of posterior tibial. Owing to the oblique direction which the popliteal artery follows, this nerve alters its relation to it at different parts of its course; until they reach the bend of the knee, the nerve is a little distance to the outer side of the artery, but superficial or posterior, and separated from it by a thick layer of adipose tissue: at the joint, the nerve is still posterior to, but in closer relation with it, and subsequently upon the popliteus muscle crosses the artery to gain its inner side. About the centre of the popliteal space, the tibial nerve sends off a small branch called the communicans tibialis, which descends superficially between the heads of the gastrocnemius, and is afterwards concealed in a groove formed by their union; it perforates, at a variable point, the aponeurosis of the leg, and, descending towards the outer malleolus, is joined a little above it by the communicans peronei, a branch of the peroneal nerve; thus reinforced, it is increased in size, and, accompanied by the posterior saphena vein, winds behind the outer ankle to be continued along the outer side of the foot. To return to the internal popliteal nerve, which sends off, while crossing the back of the joint, four or five other branches for distribution to the gastrocnemii and plantaris muscles, and also furnishes some articular twigs; these are all accompanied by corresponding branches of the popliteal artery, and from their situation are liable to be compressed by an aneurismal tumour. The external popliteal or peroneal nerve descends along the inner side of the biceps muscle, by which it is guided to the head of the fibula, and winds round the neck of that bone beneath the peroneus longus muscle to divide into its terminal branches; in the ham it gives off the small branch called the communicans peronei. This will be seen to descend over the outer head of the gastrocnemius muscle and beneath the fascia, and, piercing the aponeurosis of the leg at a very variable distance above the outer angle, joins the communicans tibialis; it presents frequent varieties both with regard to its size and the point of junction with the last-named nerve: occasionally the union occurs in the popliteal space. To reach the popliteal vessels, a quantity of fat which fills up this space must be dissected out: it is very abundant, and surrounds and supports the popliteal artery.

The Popliteal Artery is simply a continuation of the femoral, and is so named immediately after the latter vessel has passed through the elliptical aperture of the adductor muscles; this opening is bounded above by the united tendons of the adductor longus and adductor magnus muscles; inferiorly, by the union of the vastus internus tendon with that from the adductor magnus which descends to the inner condyle; externally, by the tendon of the vastus internus, and internally, by that of the adductor magnus. Passing through this tendinous aperture, the artery is at first situated on the inner side of the femur at the junction of its middle

and inferior thirds, and descends obliquely outwards and from before, backwards through the popliteal space, to the lower border of the popliteus muscle, where it terminates, after having gradually diminished somewhat in size, by dividing into the anterior and posterior tibial arteries. When viewed with regard to the vertical axis of the popliteal region, the artery certainly takes an oblique course outwards; but in reference to the mesial and perpendicular line of the body, this obliquity is more apparent than real, and depends upon the direction inwards which the shaft of the thigh bone follows; and this appears evident by the artery passing vertically and midway between the condyles of the femur. Its course from before backwards is very decided until it has attained the superior border of the popliteus muscle; but as the lower portion of the popliteus is on a plane a little anterior to the upper, and as the artery is applied upon its posterior surface the course will be changed for a direction forwards, so that the artery describes a slight curve, convex backwards, and the concavity corresponding with the back of the knee-joint. When the leg is flexed upon the thigh, the popliteal artery follows the bend of the articulation, and is curved forwards without lateral tortuosity, the curve agreeing with the angle of flexion; this alternate straightening and bending of the artery during the movements of the leg has been assigned as a reason for its being so frequently the seat of aneurism; on the other hand, it has been stated that forced extension of the leg, carried even to rupture of the ligaments of the joint, may be made without injury to the artery. The popliteal artery is closely related to its accompanying vein; as they are entering the space, the vein lies to the outer side of the artery, and superficial or posterior to it, and changes its relation near the joint only to become still more directly posterior: they are enveloped in a common sheath, which is continued from the femoral region (see FEMORAL ARTERY), and by which they are intimately connected with each other. The artery is at first deeply seated in the popliteal region, and guided into it by the inferior boundary of the elliptical tendinous opening; it then descends obliquely upon the flat triangular surface of the femur to the knee-joint, resting in its course upon a cushion of fat which is interposed between it and the bone, and thicker below than above, so as to well support the artery as it inclines backwards from the femur to reach the posterior aspect of the joint. For some distance from its commencement it is concealed beneath the semimembranosus muscle, the thick fleshy belly of which obliquely crosses it behind; emerging from under cover of this muscle, the artery continues its course to the condyles of the femur, between the biceps on the outer side, and semimembranosus and semitendinosus on the inner; a considerable quantity of fat separates it from, posteriorly, the aponeurotic fascia, closing in the space behind, and from the skin. As the internal popliteal or tibial nerve descends vertically in the axis of this region, it must necessarily lie to the outer side of the artery in this part of its course; and as the nerve is found almost immediately beneath the fascia, it is therefore superficial or posterior to the artery, from which it is separated by more or less fat. While thus buried in fat, three or four lymphatic glands are closely related to the artery, often indeed surrounding it, one to either side, another superficial, and a fourth occasionally found between it and the femur. Should any of these glands become enlarged, the impulse such swelling would receive from the artery might lead to its being mistaken for aneurism. We next find the popliteal artery crossing the bend of the knee-joint, and resting upon its posterior ligament; it descends between the condyles of the femur and the two heads of the gastrocnemius to the upper border of the popliteus muscle: the little fleshy belly of the plantaris is also related to its outer side. In this stage the accompanying vein is more directly behind it, and the tibial nerve, coming into closer relation with the artery, from which it is separated by the vein, is also posterior or superficial to it, with a tendency to cross to its inner side. At this part of its course the nerve usually sends off, first, the communicans tibialis, and then its branches to the heads of the gastrocnemius, so that the relation which the nerve and its branches have to the artery at this point will readily account for the pain or numbness generally attendant on aneurismal tumours in this region; so, also, for œdematous swelling of the leg under the same circumstances, we have only to refer to the relative anatomy of the vein and artery for its explanation; posteriorly, the artery is separated from the fascia and integument by more or less fat, and is still a considerable distance from the surface; for the tendons of the hamstring muscles, and the condyles of the femur with the heads of the gastrocnemius, so bear off from the artery the skin and fascia as to leave it in a deep and narrow hole, resting upon the posterior ligament of the joint, and concealed behind by, first, the vein, and then the tibial nerve. Of course any operation upon the artery while thus situated would be impracticable. Lastly, the artery gains the posterior surface of the popliteus muscle, upon which it descends to terminate by dividing into the anterior and posterior tibial vessels; this division occurs at the lower border of the muscle, and opposite the interval between the tibia and fibula. The artery is deeply concealed between the heads of the gastrocnemius as they approach each other to unite; the tibial nerve crosses to gain its inner side, and the vein, which often receives the tibio-peroneal vein while upon the popliteus, is still posterior to the artery.

Varieties.—The popliteal artery very seldom exhibits any deviation from its usual arrangement; occasionally, its point of division occurs higher in the popliteal space. Professor Harrison mentions to have seen the artery divide between the condyles of the femur. Instances

have been recorded of a high division of the femoral artery (see Femoral Artery), and where two popliteal arteries existed; but the artery generally appears particularly free from any variety.

Branches of the popliteal artery.—These are very numerous, and of considerable importance in maintaining a collateral circulation when the femoral artery has been obliterated by operation or disease; they are not always constant, either in number or size. The popliteal artery first sends some irregular branches to the hamstring muscles, the rami musculares superiores; then five articular arteries, two of which usually arise a little above the joint, and are called external and internal superior articular, and two below, the external and internal inferior articular; the last is an azygos branch. After giving off these articular arteries, the popliteal sends several large branches to the gastrocnemii muscles, the rami musculares inferiores.

The superior muscular branches are two or three in number, which are distributed on either side to the hamstring muscles and anastomose with the perforating arteries of the profunda. The superior external articular artery is of some size, and arises from the outer side of the popliteal at a variable distance above the outer condyle of the femur; it descends to wind round the bone under the biceps muscle, which latter it supplies and divides into superficial and deep branches; the former are distributed to the vastus externus muscle, and, by passing through its substance, terminate on the patella; the latter supply the synovial lining of the articulation, and the lower extremity of the femur itself. These branches anastomose with those of the inferior external articular artery, and with the long branches of the external circumflex from the profunda, which descend in the substance of the vastus externus towards the knee.

The superior internal articular artery arises from the inner side of the popliteal above the inner condyle, and also winds round the femur, passing beneath the tendon of the adductor magnus muscle; like the external articular, it divides into superficial and deep branches, the former penetrating the vastus internus to ramify on the patella, and anastomoses with the external articular and the anastomotica magna from the femoral; the deeper branch is distributed to the synovial capsule and femur.

The azygos branch is derived from the anterior aspect of the popliteal while it is in relation with the posterior ligament of the joint; it divides into branches which pass through the ligament, and supply the synovial membrane and crucial ligaments of the joint. The inferior external articular is given off from the outer side of the popliteal a little below the articulation, and winds round the outer surface of the external semilunar cartilage, passing beneath the plantaris and outer head of the gastrocnemius muscles; it then courses forward above the head of the fibula, and beneath the external lateral ligament to divide into branches, which anastomose with the anterior tibial recurrent and the other articular arteries. The inferior internal articular artery is generally rather a large branch, and descends to the internal lateral ligament, beneath which it passes to gain the front of the tibia; it divides into numerous branches which are distributed to the structures about the inner side of the joint, and which anastomose also with the other articular branches.

These articular branches of the popliteal are seen, when well injected, to form a beautiful network of vessels around the knee-joint; by anastomosing with the external circumflex and perforating branches of the profunda, with the anastomica of the femoral and the recurrent tibial artery, and also with each other, a very sufficient collateral circulation is usually maintained in cases where the femoral artery has been obliterated.*

The inferior muscular branches are derived from the popliteal artery while passing between the heads of the gastrocnemius; they are four or five in number, and often of considerable size; accompanied by branches from the tibial nerve, they descend in the substance of the gastrocnemii muscles, and may be traced sometimes to the tendo Achillis; generally, a small branch from one of them descends with the communicans tibialis nerve. These vessels are sufficiently large as occasionally to require a ligature after amputation of the leg.

The course of the popliteal vein has been already noticed in connection with the artery; it is remarkable for the thickness of its fibrous coat, and is formed by the junction of the anterior tibial veins with a trunk called the tibio-peroneal: this latter vessel is produced by the confluence of the posterior tibial and peroneal veins. The popliteal vein receives the veins which accompany the branches of the popliteal artery, and also, about the centre of this region, the vena saphena minor.

Operative relations of the popliteal artery.—Operations upon the artery in this region are now never undertaken, unless, perhaps, in cases of injury with an external wound, the size and direction of which will vary the surgical treatment to be adopted; a ligature may be passed round the artery in the upper part of its course as it emerges from beneath the semimembranosus muscle, the outer edge of which will act as a guide to the first incision. After dividing the fascia, the finger, sunk into the space and carried upwards upon the outer surface of the semi-membranosus, will reach the artery; the vein lies behind it, and a little to the outer side, and will therefore be reached first; the needle must be insinuated between the artery and vein, and carried round the former from without inwards. This operation is mentioned merely as being practicable; in the rest of its course the relations of the artery are such as to prohibit any surgical operation upon it.

(*William Trew.*)

PORIFERA (*πόρος φέρω, canal-bearing*). A word applied by Professor Grant to designate

* I have witnessed one instance where mortification of the leg ensued after the application of a ligature to the femoral artery for the cure of popliteal aneurism; amputation was performed above the knee.

a remarkable class of organized beings, dubiously admissible into the animal series, usually known by the name of Sponges, which are met with in great abundance in the seas of most climates, either growing in isolated masses from the rocks or spreading out so as to encrust the surfaces of submarine bodies with a kind of living carpet, the texture of which varies in accordance with the nature of the sponge. By recent naturalists, the term Amorphozoa (*αμόρφος, shapeless; ζῶον, animal*) has been considered a preferable designation, and accordingly these names will be applied indiscriminately throughout the present article.

According to the most recent authors, the members of the class before us may be generally described as follows: — "Organized bodies growing in a variety of forms, permanently rooted, unmoving and unirritable, fleshy, fibro-reticular or irregularly cellular, elastic and bibulous, composed of a fibro-corneous axis or skeleton, often interwoven with siliceous or calcareous spicula, and containing an organic gelatine in the interstices and interior canals; reproduction by gelatinous granules generated in the interior, but in no special organ. All are aquatic, and, with a few exceptions, marine." *

The families composing the class thus characterised are distinguished by the nature of the skeleton or solid framework upon which their shape depends, in accordance with which Blainville has arranged them as follows: —

Alcyoncellum. — Body fixed, soft, subgelatinous, solidified by tricuspid spicula, phytoid; branches not numerous, cylindrical, fistular, terminated by a rounded orifice, with thick walls composed of regular granules; polygonal, alveoliform, pierced with a pore externally and internally.

Spongia. — Body soft, very elastic, multiform; more or less irregular, very porous, traversed by tortuous canals, which are numerous, opening externally by distinct oscula, and formed by a kind of subcorneous substance which anastomoses in every direction; entirely without spicula.

Calcispongia.—Body not very soft, formed in irregular masses, porous, traversed by irregular canals, which open externally by oscula, and composed of a subcartilaginous substance, supported by calcareous spicula that are, for the most part, stelliform.

Halispongia (*χάλις, silex*). — Body more or less rigid or friable, in an irregular mass, porous, traversed by tortuous canals terminating by oscula scattered over the whole surface, and composed of a subcartilaginous substance supported by simple spicula, which are silicious.

Spongilla. — Body an irregular mass, more or less rigid and friable, pierced with pores, but without true oscules, composed of a fibro-cartilaginous substance, which is in small quantity compared with the great number of simple silicious spicula which solidify it.

Geodia. — A fleshy body, tuberiform, irregular, hollow internally, and formed externally by a sort of crust or envelope pierced with a great number of pores, and containing a group of oscules or larger pores placed in a little subcircular space.

Siphonia. — Body polymorphous, free or fixed, composed of dense fibres, forming two sorts of canals, some larger and longitudinal, opening by oscula at the bottom as well as on the summit, the others transverse and anastomosing, radiating towards the periphery, and provided with a terminal depression, more or less considerable, in which the oscules are collected in a radiated manner.

Scyphia. — Body cylindrical, simple or branched, terminated by a large rounded oscule, and entirely composed of reticulated tissue.

Eudea. — Body filiform, attenuated subpedunculate at one extremity, large, round, and pierced with a great oscule at the other, with pores scarcely visible in irregular lacunæ; whole surface reticulated.

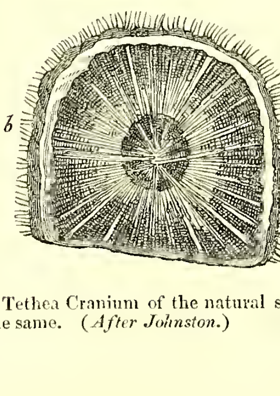
Hallirrhoa. — Body turbinated; almost regular, with the circumference circular or lobed, covered with cellules or pores, which are indistinct externally, with a large oscule in the centre of its enlarged part.

Tethium. — Body subglobular, irregular, tuberiform, sarcoid but firm, suberous, resisting, supported by and mixed up with an immense quantity of aciculi, which are simple,

Fig. 67.

a

b



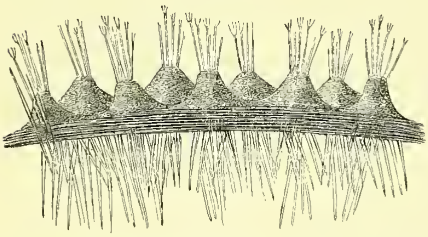
a, Tethea Cranium of the natural size; *b*, section of the same. (*After Johnston.*)

* History of British Sponges and Lithophytes, by George Johnston, M. D., Edinburgh, 1842.

fasciculate, and diverging from the centre to the circumference.

Skeleton. — The framework, or fibrous portion, from the arrangement of which the sponge derives its form is composed, as we may gather from the preceding table, of various materials differently disposed in different species, and it is upon the modifications in

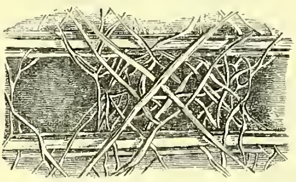
Fig. 68.



A minute portion of the surface of Tethea Cranium magnified; spicula projecting beyond the surface. (After Johnston.)

the nature and arrangement of the solid portions that the general characters of the mass depend. In the true sponges (*Spongia*), so remarkable for their elasticity and softness, and for their capability of absorbing fluids, properties which render them valuable for many important uses; the whole substance is composed of horny subcylindrical fibres, which ramify and interlace in every possible direction, anastomosing with each other so as to form innumerable continuous cells and intricate canals, the walls of which, in the recent sponge, are crusted over with the gelatinous

Fig. 69.

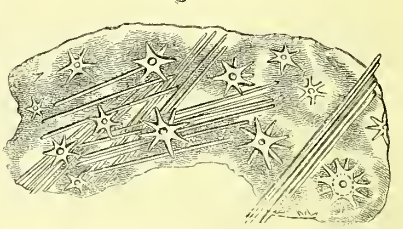


Single interspace or open cell, and surrounding finer mesh-work of the skeleton of Euplectella Aspergillum. (After Owen.)

living cortex. The horny threads composing this inextricable labyrinth are of unequal thickness, and by some writers have been erroneously described as being throughout tubular; but this latter is a mistaken view of their structure, dependent upon optical appearances, as has been proved by Mr. Bowerbank * and others, the horny fibres being, in fact, solid and imperforate.

In a second group of Sponges, called *Halichondria* (χαλιξ, silex; χονδρος, cartilage), the solid framework of the body is principally made up of silicious spicula, imbedded in the fibre or parenchyma of the sponge. These spicula, which are composed of pure *silex*, are generally united into fasciculi by an enveloping glutinous or condensed cellular substance, and by the junction of these fasciculi in various modes fibres are formed, which traverse every part of the body, forming the boundaries of canals and orifices, and giving form and support to the whole of the gelatinous or soft cellular substance of the animal.* The spicula, so far as the British species are concerned, Dr. Johnston observes, seem to be always in the shape of simple needle-like crystals (*fig.* 70); nor does any

Fig. 70.



A minute film of the rind of Tethea Lyncurium compressed between plates of glass, and highly magnified to show the needle-like and starred spicula. (After Johnston.)

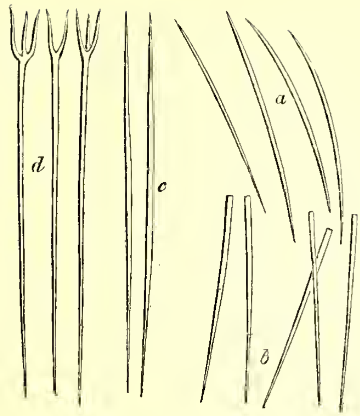
species present us with spicula of two different forms, though they sometimes vary much in length and gracility; but he cannot assent to the opinion of Dr. Grant that the form is different in every distinct species, otherwise the task of distinguishing them would be comparatively easy.†

A third group of Sponges, designated by Blainville, *Calcespongia*, has the framework which gives them form solidified by the presence of spicula, which are entirely composed of carbonate of lime: in sponges belonging to this group there is, according to Dr. Johnston, no net-work, their basis being a porous membrane, rendered compact by the profusion of spicula imbedded in it. The siliceous spicula belonging to the preceding group form mostly needle-like spines; but there are found along with them, in the genus Tethea, some that might have been the model from which mythological painters might have drawn the trident they have placed in the hands of Neptune. (*fig.* 71, *d*). The calcareous spicula are more variously shaped — either simple and acicular or clavate, or formed with three, or even sometimes with four prongs. The two kinds, viz. the calcareous and siliceous, have not hitherto been detected co-existent in any British sponge; but the spicula of every species are very constant to the same figure, although in point of size they vary exceedingly.‡ "When these spicula are examined through the microscope after exposure to a red heat, we distinctly perceive," says Dr. Grant §, "a shut

* Microscopic Journal, vol. i. p. 10.

* Grant, Comp. Anat. p. 5.
† British Sponges, p. 89.
‡ Johnston, loc. cit.
§ Edin. Phil. Journ., xiv. p. 184.

Fig. 71.



a, c, d, Spicula of Tethea Cranium; *d,* three forked spicula; *c,* fusiform spicula; *a,* cuticular spicula; *b,* spicula of Tethea Lyncurium. (*After Johnston.*)

cavity within them, extending from the one point to the other; and on the inflated part of each spiculum we observe a ragged opening, as if a portion had been driven out by the expansion of some contained fluid. In those spicula which had suffered little change of form by their incandescence, I have never failed to observe the same cavity within extending from one end to the other, and a distinct open rent on their side by which the contained matter has escaped." The existence of this central cavity has likewise been recognised by Mr. Bowerbank, who, moreover, observes, that it is " lined with an animal membrane, which becomes converted into a thin film of carbon when the spicula are exposed to the action of the blow-pipe."

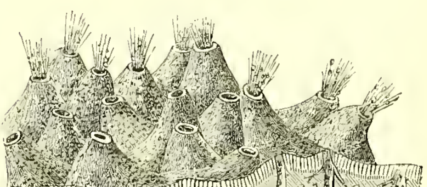
Gelatinous cortex.—" In the recent and living sponge, all its canals and pores are filled with a glairy colourless fluid like the white of an egg, which flows freely out on the removal of the sponge from the water. The quantity of this fluid varies according to the species. In some, it is copious even to nauseousness, but in the compact Halichondriæ, there is little of it, and in the Grantiæ it appears to be entirely wanting."* It " has an unctuous feel, emits a fishy odour when burnt, leaves a thin film of membrane when evaporated, and appears to the naked eye, transparent, colourless, and homogeneous, like the white of an egg: but when a drop of it is examined on a plate of glass under the microscope, it appears entirely composed of very minute, transparent, spherical or ovate granules like monads with some moisture. These monad-like bodies, nearly all of the same size and form, resemble the pellucid granules or vesicles which Trembley has represented as composing the whole texture of the Hydra, or the soft granular matter we observe in the stems of living Sertulariæ; and indeed most of the fleshy parts of organized bodies appear to be composed of similar pellucid granular or monad-like bodies in different states of aggregation."* The sensible qualities of this glairy material vary in different species of sponge, "the odour of some being decidedly animal, while others belong to common and well-known vegetables. The Spongia coalita, when newly taken out of the water, smells very strongly of the common mussel, and when burnt it still resembles the same bivalve burnt; the Spongia compressa, on the other hand, smells strongly of the common mushroom; some, as the Spongia oculata, have scarcely a perceptible odour."

* Johnston, loc. cit.

Irritability. — According to Audouin † and Milne Edwards, when a living Tethea is allowed to remain for some time perfectly undisturbed in a vessel of sea-water, its oscula may be observed widely expanded, and the currents, hereafter spoken of, passing through them may be readily observed. But if, in this condition, the animal is disturbed or removed for an instant from the water, the currents grow much feebler, or cease altogether, and the oscula, contracting slowly and insensibly, become at last almost obliterated. In other genera of sponges, however, this contraction has been looked for in vain; and although the openings of the oscula have been watched with the utmost attention, and measured at intervals with miscroscopic accuracy, not the slightest movement has been perceptible.

Circulation of Water. — In the living sponge, as was first remarked by Professor Thomas Bell, and subsequently by other observers, a constant circulation of the surrounding element, is, by some mysterious agency, kept up throughout its substance, the water being perpetually sucked in, as it were, through all the minute pores, upon the periphery of the mass, and again emitted in continuous streams through the larger orifices (oscula) of the sponge.

Fig. 72.



Living Papillaris, showing the jets of water emitted from the oscula. (*After Blainville.*)

Dr. Grant put a small branch of *Spongia coalita* with some sea water into a watch-glass, in order to examine it with the microscope, and thus describes the phenomena it pre-

* Grant, loc. cit.

† Hist. Nat. du Litt. de la France, vol. i. p. 78.

sented:—"On moving the watch-glass, so as to bring one of the apertures on the side of the sponge fully into view, I beheld, for the first time, the splendid spectacle of this living fountain, vomiting forth from a circular cavity an impetuous torrent of liquid matter, and hurling along in rapid succession, opaque masses, which it strewed every where around. The beauty and novelty of such a scene in the animal kingdom, long arrested my attention; but after twenty-five minutes of constant observation I was obliged to withdraw my eye, from fatigue, without having seen the torrent, for one instant, change its direction, or diminish, in the slightest degree, the rapidity of its course; I continued to watch the same orifice, at short intervals, for five hours, sometimes observing it for a quarter of an hour at a time, but still the stream rolled on with a constant and equal velocity. About the end of this time, however, I observed the current become perceptibly languid; the opaque flocculi of feculent matter, which were thrown out with so much impetuosity at the beginning, were now propelled to a shorter distance from the orifice, and fell to the bottom of the fluid within the sphere of vision, and, in one hour more, the current had entirely ceased."

Subsequently, two round portions of the *Spongia panicea* were placed together in a vessel of sea-water, with their orifices opposite to each other, at the distance of two inches; they appeared to the naked eye like two living batteries, and soon covered each other with feculent matter. Dr. Grant then placed one of them in a shallow vessel, and just covered its surface and highest orifice with water. On strewing some powdered chalk on the surface of the water, the currents were visible at a great distance, and on placing some small pieces of cork or of dry paper over the apertures, he could perceive them moving by the force of the currents at the distance of ten feet from the table on which the specimen rested. A portion of soft bread pressed between the fingers into a globular form was not moved away in a mass by the stream, but was gradually worn down by the current beating on its sides, and thus propelled to a distance in small flakes. A globule of mercury of equal diameter with the orifice, let fall upon it from a glass tube, was not removed or shaken, and completely stopped the current. In this condition, on piercing the sponge with a needle, a new current was established through the artificial canal thus formed, which continued even after removing the obstruction from the original orifice.

A globule of mercury of any smallness placed over the orifice of a living sponge, is too heavy to be affected by the small column of water which impels against its smooth round surface, flowing at the rate with which it issues from that orifice, and is useful in enabling us to stop up the currents of certain orifices, in order to direct the stream with greater force through a particular aperture which we wish to examine through the microscope. By adopting this plan with some sponges, which have very few and large orifices on the surface, it is distinctly perceptible with the naked eye, that the current never enters by the same apertures through which it issues, and we might thus measure the whole strength of the forces employed to produce the currents in any particular specimen.*

Various hypotheses have been suggested to account for the production of these streams of water which constantly percolate the body of the sponge, but all of them have been rejected in turn as unsatisfactory. Ciliary movement might be supposed to be the cause of this phenomenon, were it not that no observer has been able to detect, even with the most powerful microscopes, the presence of cilia in the interior of the aquiferous canals. At certain seasons, indeed, when the ciliated reproductive gemmules described by Dr. Grant are abundantly disseminated through the living cortex of the sponge, it would seem possible that they might have some influence; but as the currents appear to be equally strong at all periods, even when these gemmules are not developed, this supposition is untenable. Lastly, the laws of endesmosis have been appealed to as capable of explaining the phenomenon in question, yet even here there are difficulties not easily got rid of.

In speaking of this propulsion of the sea-water through the Halichondria, in which genus it has been principally observed, the crustaceous species being best adapted for the study of its phenomena, Dr. Johnston remarks†, "A single observation is sufficient to convince us that this circulation has nothing in common with that of higher animals, but it has some analogy surely with that imbibition and influx of water into the body of most radiated and molluscous animals which takes place through the skin and through certain canals, which Della Chiage has described and figured as their aquiferous system. The canals in both cases are not vascular tubes with membranous parietes, but rather furrows, excavated in the flesh or substance of the body, and leading into wider channels equally unlined. They have in common a direct communication with the circumfluent water, which alone ever flows in them, and the entrance of this water seems to be, in a great measure, or entirely, independent of the will of the animals; but the polypes and mollusca only have the power of expelling it when they choose by the contraction and compression of the parts which the canals traverse. There is, however, a wider difference in the arrangement of the aqueducts,—in the Radiata and Mollusca, the pattern is the same in every individual of each species, but in the Sponges it has no constancy,—so that in no two specimens of the same kind do we ever find the arrangement to be exactly alike.

This inconstancy seems to prove that the

* Edin. Phil. Journal, vol. xiii. p. 104.
† Hist. of British Sponges, p. 89.

direction of the aqueducts through the sponge, and the position of their orifices or oscula on the surface, is very much a matter of chance, and that their formation is the result of a mechanical cause liable to be diverted from its course by exterior circumstances. If we follow the growth of a sponge, we may feel still more confirmed in this view. The species begins as a spot-like crust of uniform texture, porous throughout, and nearly equally so. In this primitive, homologous condition, there is nevertheless a perfect circulation, — a current which seeks the interior, and another which flows from it, to mix with the circumfluent medium. As the sponge grows in extent and depth, the space for imbibition is enlarged, and the centrifugal water, in its efflux, flowing at first into one and then into more currents, these gradually make for themselves channels in the cellular texture, the fibres of which are pushed aside, and prevented, by the continuance of the stream, from again encroaching on its course. The channels increase in number with the continued increase of the sponge, and as it cannot but happen that they shall occasionally open into and cross each other, we have a wider canal formed by the additional flow of water into it. Such of these canals as reach the surface, soon effect for themselves an opening there; for the current in it pushes against the superficial coat that opposes its efflux, and gradually thins and loosens its texture until this ultimately disappears leaving a fecal orifice or osculum. This is frequently a simple circular hole ; but often, on looking within the outer rim, we notice in the funnel from two to five lesser oscula united together, which are the openings of so many canals that have united there ; and sometimes we find spread within the osculum, or over its mouth, a net work of finer texture than the rest of the sponge, but otherwise of the same nature and composition."

"Such, we believe, to be the manner in which the canals and oscula are formed, and hence we cannot give our assent to the notion that the net-work spread over or within them is intended as a 'wise provision'* against the intrusion of noxious animals, or other foreign bodies within the sponge, which seems indeed to be sufficiently protected at these orifices by the efflux of the currents passing continually from them. Neither can it be supposed that the position and elevation of the oscula have any foreseen relation with the situation of the sponge in the water. When, according to Dr. Grant, this production spreads level on a rock with an upright aspect, the oscula are raised into crater-like cones, to enable the sponge to clear itself of the excrementitial matters carried out by the centrifugal streams; but when it hangs pendent from the rock the oscula do not rise beyond the surface, because the necessity of ejecting excrementitial matters to a distance does not exist. This is to bestow a foresight and instinct on the sponge which even the followers of Lamarck would hesitate to give it, and which we may safely deny it to be possessed of. The form of the oscula depends entirely on the texture of the species, and on the force of the effluent currents. If the texture be loose and fibrous it yields easily, and the oscula are level, or nearly so : if more compact the skin is pushed beyond the surface into a papillary eminence ; and if too firm and dense to yield to the pressure behind, they fall into a level condition. They are also liable to be modified in some degree by external forces, for the littoral sponge, which, in a sheltered hollow, or fringed pool, will throw up craters and cones from its surface, may be only perforated with level oscula, when it is swept over, and rubbed down by the waves at every tide."

Reproduction. — The following are Professor Grant's recorded views upon this subject. "Every part of the gelatinous matter (which invests the skeleton of the sponge) is covered with minute granular bodies, which are distinctly seen in every species of sponge by the weakest magnifier of the microscope. These granular bodies are represented in the plates of Donati of a spherical form, adhering to the quadriradial fibres of what he has named the *Alcyonium primum Dioscoridis.* They are quite invisible to the naked eye ; they escape along with the gelatinous matter, and compose the greater part of it ; they are connected with each other by the gelatinous matter, and probably by the same medium, have some connection with the spicula, along which they are placed. No part in the organization of a sponge is more constant and obvious than these granular transparent bodies, lining the interior of every canal from the pores to the fecal orifices. Their form is not quite spherical, but somewhat lengthened and ovoidal, and they are always attached by one extremity to the gelatinous matter, while their opposite end is seen to project free into the cavity of the canals. Through the greatest magnifier of the microscope no difference can be detected in their forms in different species of sponge ; they all appear to be enlarged, and round at their free projecting extremity, and, when watched with attention, we distinctly see that they possess some power of spontaneous motion both when in connection with the sides of the canals and when lying isolated at the bottom of the water. The ova of the sponge are quite visible to the naked eye, and are seen disseminated through the whole texture of the sponge in the winter season. They are bodies of a

* "When we cut a thin piece of the surface of a living sponge, and look down through one of its pores with the reflecting microscope, we perceive, immediately beneath the projecting spicula which defend the pore, a very delicate network of gelatinous threads thrown over the entrance of the tube. This piece of structure is so fine as to be perfectly invisible to the naked eye; it consists of five or six threads which pass in from the sides of the tube, to be connected with a central mesh; so that there are five or six meshes thus formed; and while this soft apparatus is beautifully defended by the protecting spicula of the pore, it serves still further to guard the interior of the animal from the smallest particles of sand or the minutest visible animalcules."— *Grant, Edinb. Phil. Journ.*

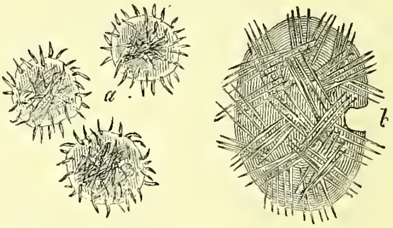
yellow colour, somewhat translucent, pear-shaped, tapering more or less at their narrow end in different species; their whole outer surface is covered with delicate projecting cilia, and when viewed through the microscope, in connection with the parent, we see that the rapid vibration of these cilia produces a distinct current in the water immediately around them, flowing always from their rounded free end towards their tapering fixed extremity, thus assisting the small granular bodies in producing the currents of the sponge during the period of their attachment to the body. They separate from the canals, and are propelled through the fecal orifices early in spring. None of these ova are seen in the sponge in summer, though we can detect no difference in the velocity of the currents at that period. For some time after they are propelled from the interior of the sponge, they swim about by means of the cilia on their surface, and exhibit all those extraordinary phenomena of spontaneous motion which Cavolini, nearly half a century ago, discovered in the ova of the Gorgonia and Madrepore. They at length fix themselves, like the ova alluded to, on a spot favourable to their growth; they lose entirely their original form, and become a flat transparent circular film through which horny fibres shoot; they soon spread, and assume a form similar to that of the parent." *

Gemmules. — Mr. Bowerbank has given the following description of the gemmules of Halichondria Johnstonia. "The gemmules of this sponge are dispersed in great abundance throughout every part of its substance; they are of an oval form, the longest diameter being $\frac{1}{217}$th, and the shortest, the $\frac{1}{294}$th of an inch. They vary considerably in size, but the above are their average dimensions. When seen by direct light, with a power of 100 linear, they appear of the same colour as the surrounding fleshy matter; but when viewed as transparent objects they assume an iron or slate-gray colour, having their surfaces closely studded with minute papillæ, which are produced by the projection of the points of numerous very small spicula, which are imbedded in the crust or shell of the gemmule, and are disposed in lines radiating from the centre to the circumference of the body."

The form of these minute spicula is exceedingly various; but the best developed ones appear conical, having their bases towards the centre of the gemmule, and their apices slightly elevating the parts of the outer integument immediately above them. The mode of disposition of these spicula is best observed, when a small portion of the sponge has either been treated with boiling nitric acid, or by incineration in the flame of a lamp. The dissolution of the gemmules is not effected by either of these agents, and, to view them with the greatest effect, they should be gently triturated with a little water between two pieces of glass, until some of them be broken into small pieces. In these fragments, the spicula may be seen in situ, cemented together apparently by siliceous matter, which appears to abound in the outer integument of the gemmule. Upon measuring some of these minute spicula in situ, Mr. Bowerbank found the average length to be $\frac{1}{3570}$ of an inch, or about equivalent to the diameter of a disc of human blood, and their average thickness the $\frac{1}{28570}$ of an inch, so that they are of exceeding minuteness as compared with those found in other parts of the same sponge.

The propagation of Tethea is by means of sporules or gemmules generated within the fleshy substance. The sporules, according to Dr. Johnston, resemble the parent

Fig. 73.



a, Oviform bodies found immersed in the parenchyma of Tethea Cranium magnified; *b*, one of these bodies viewed through the microscope after compression between two plates of glass. (*After Johnston.*)

sponge in miniature; but they have no distinct rind or nucleus, being composed of simple spicula woven together by the albuminous matter; and there seems no way of escape for them, except by the dissolution of the body of the parent sponge, which most probably is an annual production. "The naturalist *, who believes that sponges have an affinity with the fungi, will see, in these particulars, a correspondency which may strengthen his belief. The Tethea, he may say, is the sea's copy of the earth-born Scleroderma, and he may remind us that, like the sporules of sponges, the sporules of fungi are equally locomotive. The *Chaos fungorum* of Linnæus is thus described: — "Habitat uti semen *Lycoperdi*, *Agarici*, *Boleti*, *Mucores*, reliquorumque fungorum, in sua matre usque dum dispergatur et in aqua exclusum vivit et moritur, demum figitur, et in fungos excrescit. Zoophytorum metaphorphosis è Vegetabili in Animale fungorum, itaque contrario ex Animali in Vegetabile." — Syst. p. 1326.

The admissibility of sponges into the animal series is, indeed, extremely problematical, and we doubt not that among naturalists of the present day the balance of opinion would be unfavourable towards retaining them in the rank which they at present occupy in zoological classification.

(*T. Rymer Jones.*)

* Edin. Phil. Journ.; and Edin. New Phil. Journ. Vol. ii. p. 128, &c.

* Johnston, p. 82.

PRODUCTS, ADVENTITIOUS.—The difficulty of defining the term Adventitious Product with precision has so frequently been acknowledged, that we feel extremely diffident in offering a new attempt to the consideration of morbid anatomists; the more so as the recent disclosures of the microscope would probably strike the generality of persons as having, almost of necessity, simplified the task, while they have in reality rather increased its perplexity. Fully conscious, then, of the debatableness of the ground we tread on, we would apply the term Adventitious Product to *any substance which, either produced by or developed in connection with the animal frame, neither forms a natural constituent element, nor a natural secretive product, of the structures amid which it is evolved.* The qualification, "either produced by or developed in connection with the animal frame" is required to ensure the exclusion of Foreign Bodies; and the latter member of that qualification, "developed in connection with the animal frame," as plainly necessary to ensure the inclusion of Parasites, which (whether they be the proceeds of equivocal generation or evolved from germs introduced from without) are certainly not *produced* by the textures containing them.

Understood thus, (and the signification seems the widest that can, in a practical point of view, be given to the term,) the character of adventitiousness is conceived to arise in three different ways:—a substance may, in truth, be adventitious, because its *nature* is different from that of any of the natural textures and secreted materials; or because the *form* it has assumed differs from that under which it naturally occurs; or because the *situation* it occupies is one to which such substance is in the natural order of things wholly foreign. Thus tuberculous matter is adventitious, because it differs in nature from all the elementary structures and secretions; a calculus composed of lithate of ammonia is adventitious, because the form, assumed by the salt composing it, differs from that it wears as a constituent of healthy urine; and an ossification of the pleura is adventitious, because the ossiform structure forming it occupies a locality in which, in the healthy state, bone is unknown.

The amount of adventitious quality in products of these three kinds differs: it is greatest and most clearly defined, where dependent on the nature of the constituent material. Thus, in the first place, concerning the adventitiousness of cancer or pus, no doubt can ever arise; their physical and chemical characters and their essential *nature* are decisive of the point. In the second place, when a product becomes adventitious simply from the peculiarity of its *localization*, the question is often less clear; nor indeed can it in the existing state of knowledge be invariably settled. Muscular fibres have, for instance, been met with in the walls of the ureter; albumen is excreted in great quantity with the urine in certain states of disease: but whether such muscular fibres are to be considered evidences of hypertrophy or actual new products, and whether such albumen must be viewed as a totally new material of renal secretion, or as a natural element of urine in excess, depends upon the mode of decision of the preliminary questions, whether rudimentary muscular fibres do or do not naturally exist in the situation referred to, and whether albumen do or do not, in excessively small proportion, form a natural constituent of human urine. And this is not the only aspect under which it becomes practically difficult to distinguish hypertrophous from adventitious products. The two states are in some conditions of disease distinctly and intimately associated. Thus, in eburnation of the heads of bones, the proper osseous tissue undergoes hypertrophy only, while the adjacent articular cartilage becomes infiltrated with adventitious bone. Again, the fat, which forms in abundance in the liver in the so-called "fatty degeneration" of that organ, is at first merely an excess of that naturally existing in the hepatic cells, and can therefore only be regarded as a product of unhealthy supersecretion: but with the advance of the morbid change, the inter-cell texture of the organ becomes infiltrated with fat; and this fat is an adventitious product by reason of the locality it occupies. Nature here, as elsewhere, transgresses the artificial limits established for the facilities of study. In the third place, it is clear that newness of *form* implies the quality of adventitiousness in an inferior degree only — that a material naturally existing dissolved in a secreted fluid, for example, does not, when from physical or chemical causes it accumulates in solid masses, possess the quality in question to the same amount as another which is never, under any shape nor even in the minutest proportion, a natural existence.

The great number and variety of the objects to which the term Adventitious Product, defined in the manner we have just proposed, will apply (from a microscopical crystal, for instance, to the highest species of intrinsically vegetative Growths) render it necessary, *in limine*, to introduce some order into the subject. We shall consequently set out by tracing those lines of distinction which separate from each other the various objects united together by the common property of Adventitiousness.

It would, no doubt, be desirable and most strictly logical to employ some one uniform principle in establishing the various divisions and subdivisions of this, as of all other groups of natural objects, which require classification. But in the present state of knowledge, at least, systematic accuracy of this kind is unattainable. Neither the anatomy of texture or of form, the physical or chemical nature or properties of ultimate elements, the mode of formation, the physiological properties, nor the pathological influences of morbid products, will, taken singly, supply a feasible instrument of classification. All must by turns be made to contribute their share in the work. And as all previous modes of arrangement have been found to bear the impress of contemporary physiological doctrines, so will the existing impulse towards micrological study be traced in ours.

But we have not pushed the use of microscopical characters to extremes, persuaded as we are that more has been done to lower than to raise micrology in general estimation by the attempt to make it (in its present unformed state) the essential and sole groundwork of distinction of organized products.

Adventitious products present themselves in the *solid*, the *liquid*, and the *gaseous* states; and this difference of molecular condition coincides with so many pathological distinctions, that (although some objections may on "transcendental" grounds be raised to the procedure,) we shall found upon it a division of the whole into three corresponding groups. A complete description of the Morbid Anatomy of the more complex of the species composing these groups should, we conceive,* comprise that of their material or physico-chemical characters; of their origin, progress, and decay; of their intrinsic morbid changes, (for *their* lives, as the lives of the organism they inhabit, are liable to variations of health and disease, — they are microcosms within a macrocosm;) of the textural alterations they produce in contiguous parts; and of the modifications their existence entails on the solids and fluids of the economy at large. It is clear, however, that a plan so extensive as this could not be ventured on in the present work; but, as far as is reasonable, we shall pursue it.

GROUP I.

SOLID ADVENTITIOUS PRODUCTS.

The group, Solid Adventitious Products, resolves itself naturally into two great classes

CLASS I. — Non-Plastic Products or PRECIPITATES.

- SUB-CLASS I. (*Saline.*) Produced by precipitation from secreted fluids.
  - § I. *Particles.*
  - § II. *Masses.*
    - A. Calculi.
    - B. Concretions.
- SUB-CLASS II. (*Animalized.*) Produced by exudation from the vessels.
  - § I. Protein-Compounds. (certain forms of the).
  - § II. Fat.
  - § III. Sugar.

CLASS II. — Plastic Products or FORMATIONS.

- SUB-CLASS I. Products possessed of a dependent existence and derived from a Blastema. *Blastemal Formations.*
  - *Order I.* Derived from a blastema which generates cells deficient in vegetative faculty and in permanency. *Deposits.*
    - § I. Typhous Deposit.
    - § II. Tuberculous ,,
    - § III. Purulent ,,
    - § IV. Melanic ,,
    - § V. Diptheritic ,,
  - *Order II.* Derived from a blastema which generates cells possessed of vegetative faculty, but deficient in permanency. *Growths.*
    - *Sub-Order I.* Deficient in the power of destroying by infiltration the natural tissues amid which they are evolved. *Non-Infiltrating Growths.*
      - Of Protein-basis.
        - Hæmatoma.
        - Sarcoma.
        - Cystoma.
        - Angeiectoma.
        - Melanoma ? ?
      - Of Fat-basis.
        - Lipoma.
        - Steatoma.
        - Cholesteatoma.
      - Of Gelatin-basis.
        - Fibroma.
        - Enchondroma.
        - Osteoma.
      - Of undetermined basis.
        - Colloma.
    - *Sub-Order II.* Possessed of the above power. *Infiltrating Growths.*
      - Of Protein-basis.
        - Carcinoma.
  - *Order III.* Derived from a blastema which generates cells deficient in vegetative faculty, but possessed of permanency. *Pseudo-Tissues.*
    - *Sub-Order I.* Sui generis.
      - Induration-matter.
    - *Sub-Order II.* Simulating the natural tissues of the adult.
      - Extra-Vascular.
        - Epithelium.
        - Nail; Hair.
        - Cartilage.
      - Simple-Vascular.
        - Cellular; Serous.
        - Fibrous; Elastic.
        - Osseous.
        - Nervous.
      - Compound-Vascular
        - Bloodvessel; Erectile tissue.
        - Lymph-vessel.
        - Fibro and Spongy Cartilage.
        - Bone; Tooth.
        - Cutaneous; Mucous.
        - Glandular.
        - Muscular.
- SUB-CLASS II. Products possessed of independent existence and derived from a Germ. *Germ-Formations or Parasites.*
  - *Order I.* Animal.
    - Entozoa.
    - Epizoa.
  - *Order II.* Vegetable.
    - Entophyta.
    - Epiphyta.

* Vide Introductory Lecture, Lancet, 1842.

(as exhibited in the annexed table), those of NON-PLASTIC and PLASTIC compounds. The class of non-plastic compounds includes those formed of matter chemically inorganic, and also those which, though organic in a chemical point of view and animalized, yet are completely destitute of structure (for example, animal sugar, cystin, xanthin), and, consequently, in respect of physiological attributes, almost take rank with minerals. The class of plastic compounds comprehends all such as present in any degree, be it ever so rudimentary, the characters of structure. A distinction so broad as the absence or presence of structure might, *à priori*, be affirmed to form a *natural* basis of classification; and, as will be seen, products belonging to the two classes do absolutely differ in all essential particulars of their physiology and pathology.

Class I.—Non-plastic Products.

Products of this class are composed of materials either (first) completely inorganic; or (secondly) of elements, though organic, incapable of assuming organized arrangement; or (thirdly) they are formed of a union of substances of both these kinds. Of the first variety one of the most unquestionable examples is supplied by solid accumulations of calcareous salts round inorganic bodies introduced into the system from without. To the scond belong biliary calculi,—masses composed mainly of an animal substance not only unfitted to form structure, but lowered in the scale of animal existences by having a crystalline form impressed on it. Among the products belonging to the third variety may be found, for example, certain urinary calculi, compounds of inorganic saline, and structureless animal, substances.

All non-plastic products agree in being directly derived from the fluids of the body. But they are not all developed on a uniform plan. Some of them originate in the coalescence of the more solid particles of secreted fluids, after the act of secretion is accomplished; and this coalescence is essentially a physico-chemical process, primarily, of precipitation, and, secondarily, either of crystallization or accretion. Others are exuded ready formed from the vessels. And this difference in mode of origin coincides with numerous differences in pathological relations; hence it may be advantageously used in forming two sub-classes of non-plastic products; those

(Sub-Class I.): Produced by precipitation from secreted fluids.

(Sub-Class II.): Exuded ready formed from the vessels.

Sub-class I.—Saline Precipitates.

The various secreted fluids may be regarded as saline solutions, in which the proportion of menstruum and of dissolved salts is chemically accurate. If any cause affect this proportion in such manner as to lower the ratio of solvent fluid, precipitation of the solid matter must follow; or if some new substance be introduced which changes the chemical relations of the dissolved and dissolving materials, a similar result necessarily ensues. The alteration of ratio referred to may obviously arise either from diminution of the solvent, or increase of the solid, material. The latter of these states exists at the moment of secretion; the former may either exist then, or be induced subsequently to the act of secretion (in consequence generally of unnatural stagnation of the fluid in its excretory passages) by evaporation, by absorption, possibly by exosmosis, and other agencies.

But embracing in one view all the saline products found in the body, nothing can be more certain than that a primary modification in the qualities of the secretions themselves is the main agent in their generation. No point in general pathology affords matter of more curious inquiry than the causation of these changes in the character of the secretions. If in some cases observation teaches us to refer them to a local morbid power, limited in duration as in the extent of surface it implicates, in other and much more numerous instances they may be traced to the operation of a constitutional influence, itself dependent on diet, mode of life, climate, &c.

Products belonging to this sub-class present themselves in the form of

§ 1. Crystalline or amorphous particles;
§ 2. Masses.

§ 1. *Crystalline or amorphous particles.*— Although in the great majority of cases these particles are, as just explained, simple inorganic precipitates from the secretions, yet recent inquiries have distinctly shown that they are in some instances associated with organic matter, which retains the form of the saline particles after these have been dissolved away by acids. Now in respect of the mode of association of the inorganic and organic materials under these circumstances, there are three possible cases. (1.) The organic matter may simply adhere to the surface of the saline ingredients. (2.) Salts of crystalline form may lie in the interior of an organic cell, closely embraced by its wall. Otoliths are each of them, as shown by Krieger*, enclosed in a membranous vesicle. (3.) What appears to be the crystalline form of the saline matter may, in truth, be simply an accidental result of its association with organic particles, to which the form observed in reality belongs.

Crystallisation of inorganic matter arises in the human body under various conditions,—either after death or during life; and in the latter case as a natural occurrence, or as a morbid phenomenon. Crystals of these kinds are microscopical objects.

The fæces contain crystals naturally; in typhoid fever with morbid change in Peyer's glands, crystals appear to form in much greater abundance than under any other circumstances: in this disease, too, they are found heaped up near the implicated glands, instead of being scattered through the contents of the bowel; and are said, unlike those of ordinary

* De Otolithis, p. 15.

fæces, to be readily soluble in sulphuric and hydrochloric acids without effervescence.

Crystals discoverable during life in connection with acknowledged states of disease may be provisionally arranged as follows : —

Crystals forming in

(*a*), Natural secretions and excretions altered in properties	Urine, Fæces, &c.
(*b*), Products of inflammation..........	Plastic, Serous exudations, Pus, Gangrenous products, Catarrhal discharges.
(*c*), Specific fluids of	Vaccinia, Variola, Syphilis, Glanders.
(*d*), Adventitious Formations...............	Cancer, Acephalocysts, &c.

Of the natural secretions which (in consequence of alteration in their composition) are liable to contain saline matters in the form of minute crystals, the urine is by far the most important. With the strictly crystalline variety may be associated certain amorphous pulverulent precipitates. These products occur in the urine in the form of *pellicle*, *cloud*, or *sediment;* in other words, they form a thin stratum on the surface of the fluid, float between the upper and lower surfaces, or gravitate to the bottom of the containing vessel. These varying positions, appreciable to the naked eye, aid the observer in forming a rough estimate of the nature of the saline matter, and may be almost conclusive on the point. The microscopical and chemical characters combined supply, however, the real evidence from which their composition is ascertained *; in order to avoid repetition, we will defer the consideration of these characters until engaged with the subject of urinary calculi. We shall have occasion to recur, in describing the morbid substances (*b*, *c*, *d*), referred to in the above classification, to the appearance of crystals within them. But it may be stated here, as a general fact, that as the materials of all such crystals exist primarily in solution, and as absorption, evaporation, or chemical appropriation of water leads to their deposition in the crystalline form, there is a source of fallacy in the examination of preparations kept in spirits ; certain salts, combined with the aqueous part of the material examined, are deprived of their water by the alcohol, and separate in crystalline forms.

§ 2. *Masses.* — Adventitious products belonging to the present sub-class, and possessing sufficient bulk to be called masses, form an important group, divisible into two series differing from each other in a variety of important *natural* characters. Some of them are, in truth, composed wholly or essentially of saline or other non-plastic materials, precipitated from the fluids of the system ; others of similar materials, deposited in an adventitious basis, itself stromal or non-stromal. In the first series, the non-plastic compounds form the essential, if not the whole, "materies morbi ;" in the second, these compounds are merely superadded to pre-existing matter (commonly morbid) of another kind ; and such superaddition, instead of increasing the activity of functional disturbance in the system, tends frequently to weaken the destructive influence of that pre-existing matter. For the sake of convenience, bodies belonging to the first series may be termed *true calculi*, or simply *calculi;* to the second, *pseudo-calculi*, or *concretions*.

(A) Calculi. — True calculi, answering to the definition just laid down, may be deposited from almost all the secreted fluids. But of these fluids, the urine is, perhaps, the only one of which the saline and other actual constituents, independently of any materials naturally foreign to their composition, form the substance of calculi; when calculous formations occur in other secretions, foreign ingredients may almost invariably be detected. The saline substance thus met with in calculous masses, and which does not enter naturally into the composition of the secretion, (or enters in excessively small proportion,) is most commonly the phosphate of lime. So frequent is the occurrence of this salt in calculous masses on mucous surfaces, as to lead irresistibly to the conclusion that mucous membrane has a specific tendency to secrete this salt, under certain conditions of local irritation.

(*a*) *Urinary calculi.* — Various constituents of the urine are capable of accumulating individually, or in association with each other and with certain animal substances, (mucus, fibrin, albumen, fatty matters, colouring matters, &c.,) so as to form masses of variable form and size ; these masses are according to their bulk termed *calculi*, *miliary calculi*, and *gravel*. The same materials unaggregated into masses form the substance of *sediments*, *clouds*, and *pellicles*. The following are the substances which to various amounts have been recognized as the constituents of urinary calculi : uric acid, urates of ammonia, of soda, of magnesia and of lime, oxalate and benzoate or hippurate of ammonia *, oxalate of lime, xanthin or uric oxide, cystin, phosphate (neutral and basic) of lime, triple phosphate of ammonia and magnesia, carbonate of lime, carbonate of magnesia, silica, peroxide of iron, fat, extractive matter, colouring matters, fibrin, albumen, and mucus.

The coalescence of the component parts of urinary calculi is effected in three chief ways.

* As the majority of the substances included under the present head enter (though comparatively in small quantity) into the composition of healthy urine, it is necessary to observe that they, practically speaking, acquire the character of adventitious products through the *new form* they assume, when the proportion in which they accumulate increases.

* Simon remarks that the presence of the benzoate, as recorded by Brugnatelli, and of the oxalate, as described by Devergie, is scarcely compatible with the great solubility of those salts.

1. When the materials forming them are *crystalline*, minute crystals, the basis of the future calculus, go on increasing in number, though not individually in size, and by their accretion, depending upon mutual attraction, form masses. Animal matter may aid in cementing together the constituent parts, but in this form of coalescence its occurrence to any amount is accidental, and tends rather to diminish the firmness of union. Pure uric acid calculi are formed on this model. 2. When the substance forming calculi is primitively *amorphous*, no attraction exists between the minute particles forming the deposit; hence a medium of union or cement is necessary. This is furnished by animal matters secreted with the urine, or thrown out by the surfaces along which it passes. The quantity and quality of these matters being liable to vary, the general aspect of the resulting calculus, and its properties of density, &c., must be subject to similar variety. Impure urate of ammonia calculi illustrate this mode of formation. 3. In the third species of aggregation, saline particles in a semi-liquid state form a sort of thick magma, as particularly insisted on by M. Civiale *; the condensation of this magma produces a uniform mass, or small spherical bodies, or simply a pulverulent matter. This mode of formation is chiefly observed in oxalate of lime calculi, but occurs also in the uric acid species mixed with various salts (*e.g.* in a calculus in the University College Collection composed of uric acid, urate of ammonia, triple phosphate and phosphate of lime), and in the phosphatic.

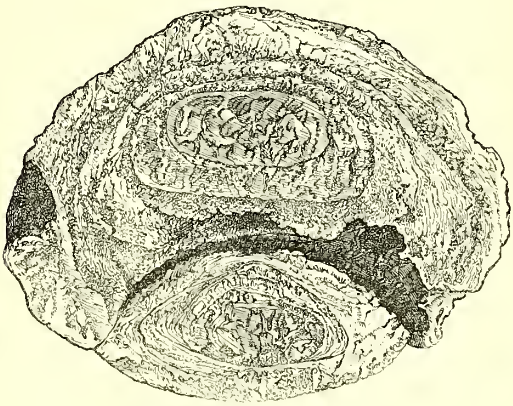
The first deposition of matter from the urine in these cases depends upon some one or more of the causes we have already enumerated in speaking of the precipitation of the saline constituents of secreted fluids generally. If this matter be not expelled from the body, it acts in various ways as a source of further deposition and accumulation around itself; it is for this reason called the *nucleus*, and the matter accumulated around it the *cortex*, of the entire mass. Every calculus may hence be theoretically resolved into a nucleus and cortex; but it is not the practice to give the central part the former name, unless it be distinctly different in composition, or, at least, in aspect, from the matter immediately investing it; there are, therefore, practically speaking, non-nuclear calculi, of which the pure uric acid and cystin species furnish examples.

The *nucleus* of a urinary calculus, although commonly formed of sedimentary saline matter, may likewise consist of various materials not naturally existing in the urine, and these materials may be either formed in the body or introduced from without.

First: sedimentary nuclei may be composed of any one of the more important materials (with perhaps a single exception) detected in urinary calculi; of these uric acid and oxalate of lime are the most common, while the phosphate of lime and triple phosphate hold the opposite position in the scale. A law established by Dr. Prout, that "a decided deposition of the mixed phosphates is not followed by other depositions," is, with few exceptions, universal. Cystin has not (as far as we are aware) been found playing the part of a nucleus in any recorded case; to this statement a large calculus of cystin surrounded with a very thin coating of phosphates (Univ. Coll. Museum) cannot fairly be considered to supply an exception.

A calculus commonly contains a single nucleus only; but instances are not wanting of calculi containing two, three, and more nuclei. Masses of the latter kind are probably simply aggregations of smaller ones, as appears to have been the case with that exhibited in *fig.* 74.

Fig. 74.



Calculus with "double nucleus," probably a double calculus. (Univ. Col. Mus.)

The mode of connection of the nucleus and cortex varies. (1.) The union may be intimate and general by every point of the apposed surfaces; this is the most common case; (2.) the nucleus may adhere to the cortex by asperities on its surface only; empty spaces, or spaces filled with grey gritty matter, being interposed between them: (3.) the nucleus may be free in the centre of the mass. Of the latter rare state a striking specimen exists in University College Museum; the surface of the nucleus is covered with dark-coloured matter in powder (dried and altered blood), some of which helps to fill the cavity existing between the nucleus and cortex.

The nucleus (when of the present species) is generally the hardest part of a calculus. It forms either in the kidney, or, much more rarely, in the bladder.

Secondly: animal matter, having such characters as render it impossible, according to Berzelius, to determine whether it is composed of mucus or of albumino-fibrinous substance,

* Traité de l'Affection Calculeuse.

almost constantly occurs in calculi, and sometimes forms the nucleus of a mass. Howship has figured a remarkable specimen, voided from the urethra of a negress, in which the nucleus consisted of "mucus," associated with a very little phosphate of lime, — the cortex of more solid phosphates. Clots of blood occasionally form the central part of calculi; a fact noticed first by Frère Côme.

Thirdly: foreign bodies, introduced from without, not very unfrequently constitute the nuclei of urinary calculi. In the great majority of cases these bodies are directly pushed into the bladder; but in some well-authenticated cases have reached that viscus after having been swallowed or otherwise introduced. Among bodies acting as nuclei have been met pins (Univ. Coll. Mus.), needles, tooth-picks, ear-picks, pieces of wood, stems of plants, ears of corn, grains of corn, stones of various fruits, tubes of various kinds, glass or earthen, &c., pieces of bougies and catheters, balls and other metallic bodies, a globule of mercury,* pebbles, &c. When the bodies thus introduced are sharp, as pins, they sometimes protrude beyond the calculous matter, and (a fact surgically important), are fixed in the surrounding tissues.

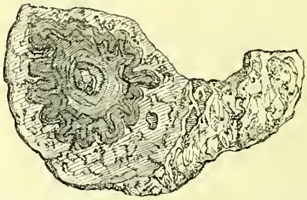
Instead of a nucleus the centre of a calculus may present one or more cavities of variable size and shape, almost invariably lined with a black pulverulent or laminar matter, and sometimes containing powdery substance; in other instances, there is neither surrounding nor contained matter of this kind. It has been supposed that in all these cases an original vegetable or animal nucleus had been gradually removed by a process of decomposition and subsequent filtration through chinks in the cortex.

The prominent physical characters of the *cortices* of calculi divide them into two natural classes; the (*a*) granular or irregular, and the (*b*) laminated.

(*a*) Of granular calculi the best example is supplied by oxalate of lime, but the appearance of these masses is not always identical. Sometimes the mass looks homogeneous and non-granular, manifestly from the close aggregation of the original granules. In the more ordinary cases the granules remain distinct, whence the well-known tuberculated or mulberry-like aspect. Uric acid calculi, rendered impure by association of certain saline matters, assume the granular form; the phosphates are sometimes granular; and the pulverulent character of the fusible calculus allies it to this species.

(*b*) In laminated calculi the cortex is, as the word implies, composed of successive layers. Although each layer may and generally does differ in thickness from others, its own thickness at its different parts may be said to be commonly pretty uniform; nevertheless to this there are exceptions, and it is manifest that whenever the cause of accretion is in greater activity towards one aspect of a calculus than another, there the lamina in course of deposition must be thicker than elsewhere. Now in conformity with a general principle already laid down, we should expect the phosphates, which are formed in consequence of local irritation in particular places, to furnish the most frequent instances of irregular thickness; and such is in truth the fact, though, as is proved by the annexed cut (*fig.* 75), not always so.

Fig. 75.



Oxalate of lime nucleus; the cortex (circular and conoid parts) impure uric acid. (U. C. Museum; patient of Mr. Quain.) The spherical part was probably seated in a sacculus.

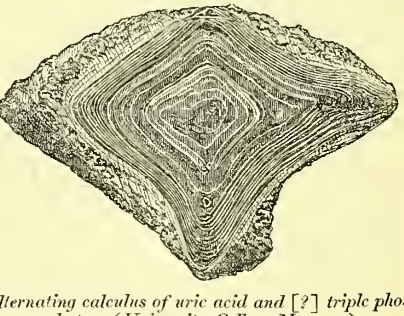
The mode of union of the laminæ differs; it may be so intimate that the line of separation is lost at certain points of the apposed surfaces; in other cases the union is imperfect and loose, and interspaces of some width are left between those surfaces.

The section of a laminated calculus is sometimes marked by lines radiating from the centre to the periphery, cutting the laminæ into segments of unequal size. This is obvious in certain cystin calculi, in some of uric acid, and in many of the mulberry species.

The tint of the different strata of a calculus, composed essentially of one substance, is not always the same throughout; nor are strata, the same in composition and separated by materials of other kinds, generally of the same hue. These varieties must depend upon irregular admixture of impurities.

Calculi composed, at least essentially, of a

Fig. 76.



Alternating calculus of uric acid and [?] triple phosphate. (University College Museum.)

* See Malago, in Filiatre Sibezio, 1845; or Simon's Chemistry, by Day, vol. ii. p. 440. In the University College Collection is a triple phosphate calculus, having the tibia of a fœtus for its nucleus. The pregnancy had been Fallopian, and ulceration having occurred between the adherent tube and the bladder, the tibia (with probably other portions of the skeleton subsequently otherwise disposed of,) made its way into the latter organ, and became encrusted abundantly with phosphates. The calculus, presented to the College by Mr. Liston, was given to him by Dr. D. R. Lietch.

single substance, are termed *simple;* of several, *compound.* When the different materials are applied in successive laminæ, the calculus is said to be *alternating* (*fig.* 76); when they are irregularly mingled it is called *mixed.* The relative frequency of the three kinds may be deduced as follows from tables printed by Dr. Prout. Of 1520 calculi there were

SIMPLE, 709; *Alternating*, 787; *Mixed* 24.

The mode of succession of various substances in the formation of alternating calculi (they may consist of two, three, four, or several successive strata), is pathologically important, and has been specially investigated by Dr. Prout. The nature of this work prevents us from entering into the subject, but we may mention (as evidence of the generality of Dr. Prout's law, that the existence of mixed phosphates in a calculus excludes the subsequent deposition of other matter), that of 566 alternating calculi composed of two layers, two only were examples of a nucleus of phosphates with a cortex of another kind of salt; that of 172 calculi formed of three layers, not one had a phosphatic nucleus, and in only three was the middle stratum composed of phosphates; and that, lastly, of 25 calculi containing four distinct layers, not one had a nucleus of phosphates; in one only was the second layer, and in three only was the third layer, thus composed. It is, however, right to observe that if small quantities of phosphates, not forming actual layers, were taken into consideration, the exceptions to the law would be much more numerous.

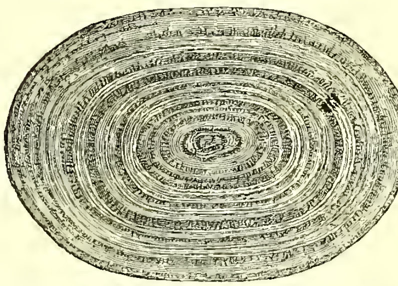
The degree of rapidity with which calculi form and acquire bulk depends upon the constitutional condition of the individual in whom they form, much more than upon the nature of their own ingredients; for, if it be true that oxalate of lime and uric acid calculi commonly enlarge slowly, and the phosphatic species with great quickness, instances of the direct contrary are far from uncommon. The cases in which calculous matter accumulates round a foreign body are obviously those, and those alone, in which perfect accuracy as to dates can be obtained; now cases are on record showing that some weeks suffice in one case for as abundant accumulation of phosphates as several months in another. The slower the enlargement, the greater, *cæteris paribus*, the density of the mass. In this latter quality calculi vary exceedingly, some being as remarkable for their porousness and openness of texture, as others for their compactness and closeness. Their specific gravity, according to Fourcroy, varies from 1213 to 1976, water being 1000; Scharling found it in one instance to amount to 2014.

Calculi are commonly solitary; from some calculations, which have been made on a limited scale, it would appear, however, that in one of every five or six cases of calculous disease two or more calculi are met with. The number and size of these bodies discovered in the bladder are sometimes almost marvellous; thus Rodrigue de Fonseca refers to a case in which that viscus contained fifty as large as nuts; fifty-nine were found in Buffon's bladder; and Moraud counted six hundred and seventy-eight in the bladder of an old man, and nearly ten thousand in his kidneys. Probably miliary calculi only accumulate in such extraordinarily great numbers.

We shall now briefly consider the physical and chemical characters of each calculus in particular, — appending in each instance an outline of the qualities of its component material, when occurring in the form of urinary sediment.

1. The *uric acid* calculus is generally of oval shape and somewhat flattened, ranges in weight from a grain to six or seven ounces and upwards, and varies in size within corresponding limits; the calculus, from a section of which the subjoined cut is reduced, measures $2\frac{5}{8}$ inches in breadth and $3\frac{3}{8}$ inches in length. The

Fig. 77.



Section of an uric acid calculus. (*Univ. Coll. Museum.*)

external surface, commonly smooth, may be finely granular, and its colour brown of different tints and depths, unless it have received a thin coating of phosphates. On section it is generally found to be laminated, and when comparatively pure its fracture has a crystalline look; when the contrary, the appearance is that of aggregated amorphous particles; the general colour is that of the external surface (much impurity may, however, render it gray or otherwise alter it), but the different strata may vary very considerably in depth of hue from yellowish-brown to mahogany colour, according to the amount of colouring matter present in each; its density is high in the direct ratio of its purity. Absolute purity never exists; all uric acid calculi contain colouring, and, with rare exceptions, fatty matters, some mucus or albumen, and besides, minute quantities of urate of ammonia, of soda, and of potash, with occasionally carbonate and phosphate of lime.

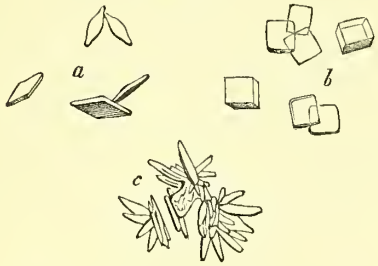
In 251 of the 763 alternating calculi, the composition of which is given by Dr. Prout, the nucleus consisted of uric acid.

Uric acid occurs as an ingredient of urinary sediments, and although not, as Berzelius supposed, their chief material in persons in health, (the amorphous urates vastly exceed it in abundance,) it may in cases of gout form the entire of the deposit.

Under the microscope uric acid appears in the form of semi-transparent, thin rhomboidal scales, of slightly yellow tinge, generally, from impurity (the pure acid being brilliantly white),

insoluble in cold and hot urine and in weak acids, soluble with effervescence (from equal volumes of carbonic acid and nitrogen) in concentrated nitric acid, the mixture acquiring a purple red hue (from murexide) at the close of evaporation, and very sparingly soluble in concentrated muriatic acid. (See *fig.* 78, *a.*)

Fig. 78.



Crystals of uric acid.

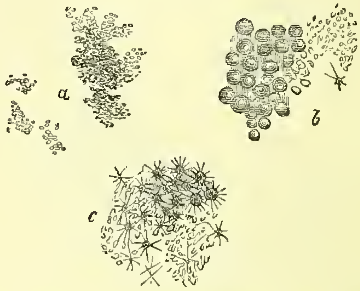
Sometimes (and less rarely than has been supposed) the rhomboidal prisms are thick, solid-looking, and cuboid in appearance. We have lately seen a *pellicle* (non-irridescent) of bloody urine after scarlatina formed of crystals of this kind (*fig.* 78, *b*). Sometimes, again, fragments of, or entire, crystals unite so as to form lanceolate or stellate figures; this form may be produced (as shown by Rayer, *fig.* 78, *c*) by artificial precipitation.

2. The *urate of ammonia* calculus (of which the existence was denied by Mr. Brande, on the plea that the ammonia evolved from certain calculi is in reality derived from associated triple phosphate, or from urea and the ammoniacal salts of the urine,) is said by Fourcroy and Prout to be rare, and more frequent in children than in adults, a statement which has been copied by various writers. The tables collected by Dr. Prout show that of 709 simple calculi 59 were composed of urate of ammonia nearly pure, 159 mainly of this salt mixed with variable proportions of the urate and oxalate of lime and phosphates. The shape of this calculus is more irregular than that of uric acid masses, but still inclined to the ovoid; it does not reach any large size, and has a smooth or granular surface. Internally it is laminated; of clay colour; its fracture earthy, and its density considerably less than that of lithic acid. Of 163 alternating calculi grouped in Dr. Prout's tables we find that 239 had a nucleus of pure urate of ammonia. In the majority of cases, then, this salt or uric acid forms the groundwork of calculous accumulation; for they constitute either the entire mass, or the nucleus, of 938 among 1473 calculi of ascertained composition in the following proportions, exclusive of many others in which they were mixed irregularly with other saline matters.

	Calculus.	Nucleus.
Uric acid, ...	230	251
Urate of ammonia pure and impure	218	239
	448	490
	938, or 1 in 1·6	

Urate of ammonia is the chief constituent of the pulverulent sediments of urine voided by healthy persons: it is insoluble in cold, soluble in hot, urine. It is commonly distinguished microscopically as a pulverulent closely packed matter (*fig.* 79, *a*); in other instances it wears the form of globules of black colour * (*fig.* 79, *b*); when alkaline reaction is established (or sometimes, as we have seen, while the urine is still acid) these globules become stellate from the formation of minute silky needles apparently springing from their circumference (*fig.* 79, *c*).

Fig. 79.



a, b, c, Deposits of lithate of ammonia. (*After Rayer.*)

Treated by dilute nitric acid, the pulverulent matter is converted into rhomboidal crystals of uric acid, *fig.* 78. Collected on a filter and washed with rectified alcohol, the residue of the amorphous matter, treated with potassa, disengages ammonia, to be detected by the smell, test paper, and hydrochloric acid. The forms *b* and *c* cannot be confounded with any other substance; the pulverulent form might be mistaken for phosphate of lime, and the modes of distinguishing the two precipitates are explained with the description of the latter. The forms *b* and *c* (first described by Quevenne) we have repeatedly observed in the sediment of urine containing lithates in abundance. Though mainly composed of urate of ammonia, the acid is apparently in union also with potass, *soda*, lime, and magnesia. Quevenne considers that they may in some sort be regarded as products of putrefaction, as they do not appear until the urine has stood for about three days; but this is decidedly erroneous, as we have repeatedly seen the simple globular, and sometimes the stellate globular, forms in urine which had not stood twenty-four hours.

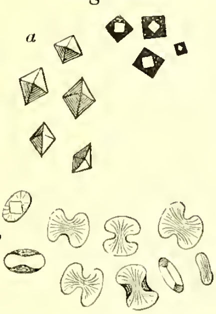
3. The *oxalate of lime* calculus is generally more or less accurately spherical in shape; though commonly of rather small or moderate size, it may acquire very considerable bulk: a model of a mulberry calculus, now before us, (Univ. Coll. Museum) measures $7\frac{3}{4}$ inches in circumference, and some of the prominences on the surface reach five lines in height. Of dark brown, purplish, blackish, or olive colour, this

* This form, which we are in the habit of familiarly calling the "globular lithate," is not exceedingly uncommon. In the numerous instances in which we have met with it, we have, however, failed in ascertaining the particular condition regulating its occurrence.

species of calculus is remarkable for the rough tuberculated character of its surface, which gives it the aspect of a mulberry. Its section exhibits commonly a granular, but sometimes a laminated, arrangement; the internal colour is the same as the external; the density and hardness (especially of the laminated variety) vary considerably. The dark colour of these calculi is generally ascribed to admixture of the colouring matter of blood, thrown out from the irritation their rough surface produces on the tissues it comes in contact with. The oxalate of lime calculus may occur of pure white colour, with sharp angular crystals on the surface; of this rare variety the University College Collection contains a remarkable specimen.

The rarity of oxalate of lime crystals in urinary deposits was matter of received opinion until the inquiries of Dr. G. Bird led him to the inference that in the cases of disease occurring in London . . . the oxalate of lime is of far more frequent occurrence in urine than the deposits of earthy phosphates.* The oxalate deposit, when in abundance, appears to the naked eye, after the application of gentle heat, as a white glistening powder, which under a low magnifying power resolves itself into "crystals of the oxalate in beautifully formed transparent octohedra, with sharply defined edges and angles (*fig.* 80, *a*). It sometimes happens that

Fig. 80.



the oxalate is present in the form of exceedingly minute crystals; it then resembles a series of minute cubes, often adhering together like blood-discs: these, however, are readily and distinctly resolved into octohedra under a higher magnifying power. If the crystals be collected and ignited on platinum foil, oxalic acid is decomposed and carbonate of lime left: the subsequent addition of dilute nitric acid dissolves the residue with effervescence." The crystals are insoluble in boiling acetic acid or liquor potassæ.

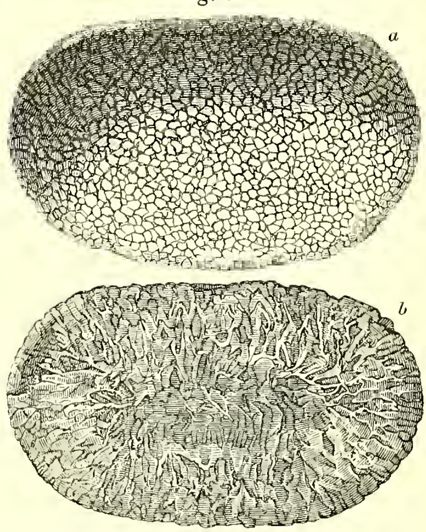
Dr. Bird describes certain dumb-bell shaped crystals (*fig.* 80, *b*) with finely striated surfaces, as a variety of form of oxalate of lime. We have frequently seen such bodies, but cannot regard their chemical nature as established.

From a table, which we have drawn up from the daily record of 84 unselected cases (42 of each sex) in our wards at University College Hospital, the following inferences may be drawn concerning oxalate of lime crystals. They (octohedral form) are of somewhat more frequent occurrence in females (14 of 42) than in males (11 of 42). They are most frequently present in acute affections and in anæmia; and at that period of acute affections when anæmia is most likely to be fully developed, at the onset of convalescence. They occur in spermatorrhea temporarily. Their frequency in rheumatism has been exaggerated, our proportion being only 3 of 15 cases. They are not present in all cases of any given disease, and probably originate in some special condition of the blood. Observation continues to exhibit to us the frequency of a deposit of oxalate of lime crystals, at the period of convalescence of acute diseases; so much so that we regard their sudden appearance in an acute disease as a *sign* of that fortunate change. This deposit is of temporary (say a few days) duration, and not to be confounded with the more or less permanent condition appertaining to a peculiar diathesis.

* On Urinary Deposits, p. 123. 1844.

4. Of the *cystin* or *cystic oxide* calculus there are two varieties, physically considered; and the physical peculiarities are probably referable to chemical differences. The *pure* cystin calculus is of oval shape, acquires moderate size; its surface, tolerably smooth, has a crystallised aspect. Internally it appears formed of a multitude of irregularly aggregated crystals, with their edges rounded off, and has the colour and shining look of bees'-wax *fig.* 81). Small portions broken off are semitransparent; an ammoniacal solution gives thin lamellar hexagonal crystals by evaporation.

Fig. 81.



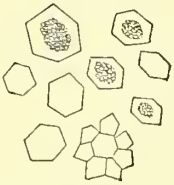
Pure cystin calculus, (long diameter nearly $2\frac{1}{8}$ *inches, short ditto* $1\frac{3}{8}$.) *Univ. Coll. Mus.*
a, external surface; *b*, section.

Foreign to the natural constitution of the urine, cystin is of very rare occurrence as a morbid precipitate. It appears as a pale nearly white pulverulent matter, insoluble in water,

in urine (cold and hot), and in acetic acid. It is soluble in ammonia, from which solution it may be obtained by evaporation in the peculiar crystalline form (*fig.* 82), visible with the microscope only. Cystin is soluble without effervescence in nitric acid; from this solution silky crystals of aciculated shape and brilliant white colour may be obtained by evaporation. Treated with nitrate of potass, the sulphur (26 per 100 nearly) contained in the cystin passes to the state of sulphuric acid, discoverable by a salt of baryta. Cystin exhales a peculiar phosphorus-like odour when burned on platina.

The crystalline form of cystin is the hexagonal prism; the crystal is transparent, more or less regular, and varies considerably in size (*fig.* 82).

Fig. 82.



Crystals of cystin: some are of much larger size than those represented.

5. The *phosphate of ammonia and magnesia* calculus (triple phosphate) is generally of oval or rounded shape, but may be of irregular form; when constituting the entire substance of a calculus (which is rare), it is of small size usually; its external colour is whitish; its surface uneven and crystalline. Internally it is generally granular and opaque, though occasionally laminated and somewhat transparent; in the former case of porous texture, in the latter compact and dense, and of dirty white colour.

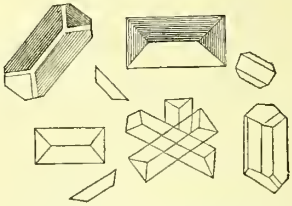
6. The *neutral phosphate of lime* calculus, remarkable for the smoothness of its exterior, is of pale brown colour, moderate size, and great rarity, — so much so that to the chance experience of Dr. Wollaston almost alone are we indebted for what is known of its characters. It is composed of laminæ, easily separable from each other, and striped transversely.

7. The *phosphate of ammonia and magnesia and phosphate of lime* (*mixed phosphates* or *fusible*) calculus is of irregular shape, often of large size, white colour, and roughish surface. In the majority of cases its section looks like a piece of chalk of loose texture, being homogeneous, non-laminated, and minutely porous; in other instances it is lamellar, and between the laminæ minute shining crystals of triple phosphate may often be detected. It marks the fingers or other bodies like chalk.

Phosphoric acid exists in healthy urine in combination with ammonia and magnesia, in such proportion as to form a perfectly soluble salt. If the proportion of base increases, the salt becomes insoluble, and, according to the amount of excess, is deposited either as the neutral or a bibasic triple phosphate.

The *neutral phosphate of ammonia and magnesia* (the only one observed in urine at the moment of emission) occurs in white transparent crystals of perfectly regular forms, referable to the right rectangular prism (*fig.* 83).

Fig. 83.

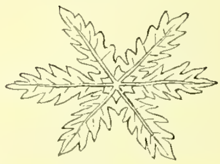


Neutral phosphate of ammonia and magnesia; crystals of spontaneous formation.

These crystals are often mixed with amorphous powder, commonly composed of phosphate of lime, rarely of urate of ammonia. They are instantaneously soluble in weak acids, and the solution is precipitable by ammonia in the form of the bibasic phosphate.

The *bibasic phosphate of ammonia and magnesia* does not appear to exist in urine, even the most strongly alkaline, at the moment of emission. But its crystals are developed with the progress of decomposition, and may be obtained from any urine by rapidly adding large quantities of ammonia. Microscopically (*fig.* 84) these crystals appear aciculated and grouped at angles of 60°, so as to resemble a pinnate or bipinnate leaf.

Fig. 84.



Bibasic phosphate of ammonia and magnesia.

Phosphate of lime occurs as an amorphous powder; very soluble in acids, it does not effervesce under their action, like the urate of ammonia, nor, like that salt, furnish crystals of uric acid under the same circumstances; when the phosphate has been dissolved in an acid, ammonia precipitates a white amorphous mass from the solution.

8. The *xanthic oxide* (*uric oxide*, *xanthin*, *urous acid*) calculus is of extreme rarity; four examples only (analysed by Marcet, Laugier, Stromeyer, and Dulk,) have as yet been met with. The external surface is described as smooth and polished, and of light brown colour. Some fragments of the calculus analysed by Stromeyer are preserved in the University College Collection; their fracture is sharp, their colour pinkish brown; they are composed apparently of easily separable concentric laminæ, and are very hard; they become waxy-looking when rubbed. Marcet's specimen weighed 8 grains, that of Stromeyer 338 grains, that of Dulk 7 grains; those examined by Laugier were very small. In Dulk's case

the oxide formed the cortex of a uric acid nucleus; in the others it was the sole ingredient. Unger has discovered minute traces of a substance which he considers closely allied to, if not identical with, xanthin in guano: its precise chemical relations, however, appear to be as yet not fully determined.

Observations are wanting concerning the characters of uric oxide sediments: Berzelius says they are pulverulent and grey.

9. The *carbonate of lime* calculus, very rare in man, is not uncommon in graminivorous animals. Dr. Prout has seen some small calculi from the human subject consisting of this salt, of perfectly white colour and very friable. The carbonate may, however, be impure, and the mass accordingly vary in colour from yellow to brown and red. This species has been observed by Smith with the appearance of a mulberry calculus *, by Brugnatelli, Frommherz, Walther, Loir, and others. Wood † has described two of pearly, and Rampold ‡ one of metallic lustre.

10. *Carbonate of magnesia*, according to Berzelius, very probably exists in all calculi composed of carbonate of lime. It appears to have been actually detected in two instances only, — once by Moscati, once by Lindbergson.

11. *Urate of magnesia* has been found forming the chief mass of two calculi by Scharling; urate of ammonia was likewise present.

12. *Urates of soda, potassa, and lime*, never form the entire mass of a calculus. The former was found in large quantity by Lindbergson in the calculus just referred to. It is uncertain whether urate of soda exists naturally in the urine; it occurs in association with uric acid and urate of ammonia in sediments, as already mentioned.

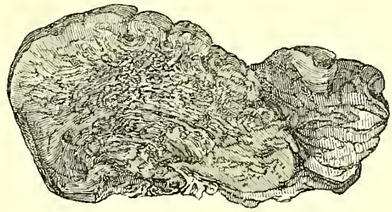
13. *Phosphate of magnesia* is, according to Brugnatelli, of common occurrence, either mixed with triple phosphate, or forming alternate layers with it.

14. *Chloride of sodium* never forms the substance of calculi, and the conditions under which this salt crystallizes in the urine are not well ascertained: partial evaporation of the fluid must first take place. The crystals are octahedral, and have their planes indented like steps of stairs.

The nature of the so-called *fibrinous* calculus (originally described by Dr. Marcet) has been made matter of question by Berzelius. It appears that the material supposed to be fibrin by that analyst was soluble, though not readily so, in nitric acid,—a character not belonging to either fibrin or albumen. This, with other of its properties as detailed by Marcet, leads Berzelius to regard the matter as inspissated vesical mucus.

The Museum of University College contains a "fibrinous calculus" taken from the bladder of a cow (*fig.* 85). It is of irregular elongated shape, measuring two and a half by one and a half inches; very light; elastic; of brownish grey colour internally, whitish externally, and coated with a white earthy crust.

Fig. 85.

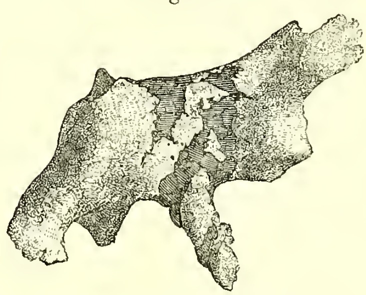


Section of fibrinous calculus.

A new substance has recently been added to the list of constituents of urinary calculi by Heller *, under the title of *urostealith*. This substance is said to form a soap with alkalies, and to have been discharged in small masses varying in size from that of a hemp seed to that of a small nut.

Each particular division of the urinary passages is the seat occasionally of calculous formations, and the characters of these are in each site more or less peculiar. Into the description of these characters we cannot here enter seriatim; of the varieties thus depending upon the seat of the product — namely, *renal, ureteral, vesical, prostatic, urethral*, and *præputial*, — the most important, the vesical, may be considered to have been specially kept in view in the preceding pages. As respects renal calculi we must content ourselves with illustrating by a figure (*fig.* 86) the curious branched form

Fig. 86.



they sometimes assume, as they gradually mould themselves to the interior of the pelvis and infundibula.

Renal calculi sometimes attain great bulk. Among numerous examples of the fact we may refer to a case seen by Wilson†, in which the kidney, perfectly atrophous, and replaced by a multilocular membranous sac (the dilated pelvis and infundibula) contained an oxalate of lime calculus weighing seven ounces and a half. Renal calculi derive much of their practical interest from their tendency to produce such atrophy of the kidney, with pyelitis (U. C. Mus.) or, more rarely, hydronephrosis.

* Med. Chirurg. Trans. vol. ix. p. 14.
† Med. and Phys. Journ. vol. lvii.
‡ Schmidt's Jahrbüch, B. v. S. 379.

* In seinem Archiv, Bd. ii.
† Lectures, p. 122.

Calculi of the prostate gland are (sometimes at least) essentially different in nature from urinary calculi, and belong to the class produced by morbid secretions from mucous surfaces. Sometimes single, they are more generally numerous; in the latter case, though occasionally found of much greater bulk, they rarely exceed a pea or small nut in size. One variety of prostatal calculus is, according to Dr. Prout, found in the natural cavities of the gland, before this becomes much disorganized; the calculous masses referable to this variety are of more or less rounded shape and yellowish-brown colour. Another variety seems to be generally found in an enlarged cavity or abscess of the prostate gland, and sometimes has a highly polished porcellanous appearance. But that this distinction is rather an artificial than a natural one appears from the similarity of composition of both varieties. As first shown by Wollaston, these calculi consist mainly of phosphate of lime and animal matter with carbonate of lime in variable proportions.

Præputial calculi and those found in *urinary fistulæ* belong, in the great majority of cases, to the class of saline masses generated through irritation of mucous (or pseudo-mucous) surfaces, and accordingly consist wholly of earthy phosphates. There is no reason, however, that a particle of gravel, or a minute calculus of various chemical constitutions, might not make its way into these situations, and become the nucleus of further deposit: and in point of fact Romer found uric acid, phosphate of lime, and animal matter in some calculi removed from underneath the prepuce of a child affected with natural phymosis.

(*b*). *Lachrymal calculi.* — Calculous formations in the lachrymal organs, positively speaking rare, are much less commonly met with in the gland and its excretory ducts than in the folds of the conjunctiva, in connection with the caruncula or in the lachrymal canals and nasal duct. They may be known by the generic name *dacryolith*, (from δακρυον, a tear, and λιθος, a stone,) first proposed by Walther.

An example of the actual formation of such calculous masses in *the excretory ducts of the gland* occurred in the case of a female, aged 19, who came under the notice of Mr. R. H. Meade, (Med. Gazette, 1835.) Twenty-three calculi, of small size, (the largest about a line in diameter,) rough, very hard, and of dirty white colour, were discharged from the ducts in the course of four or five days. They consisted principally of phosphate of lime, with a small quantity of carbonate of the same base and traces of animal matter. Von Walther describes a curious case, in which calcareous matter continued to be formed in *the folds of the conjunctiva* during a space of about ten weeks. The first mass formed was of angular shape, about the size of a pea, and easily capable of being rubbed down into a greasy powder. It reappeared in three days; and subsequently a similar matter formed in the other eye. The deposition ceased under the use of potash internally, but returned three years after; carbonate of lime chiefly, with phosphate of lime and animal matter, were its constituents. Numerous examples are on record of such concretions occurring in the follicles of the *caruncula*. Sandifort, Blegny, Schmucker, Mr. Travers, and others have seen calcareous matter in the *lachrymal canals*. Krimer* has described a calculus of the size of a small pea, of ash-grey colour, polished, of calcareous appearance, removed from the *nasal duct* of a woman, who for nine months had laboured under disease of the lachrymal passages.

There is a species of calculus, essentially of fatty nature, commonly known as "deer's tears," which forms in the fossa just below the anterior canthus of the adult red deer (cervus elephas). It yields on analysis resin with ethereal oil, fatty oil, wax, cellular substance, colouring matter, chloride of sodium, and phosphate of lime. Some of these ingredients are supposed to be derived from hair, which is usually entangled with it. It is said to possess the medicinal virtues of the fœtid antispasmodics.†

(*c*). *Nasal calculi.* — Calculous masses are not extremely uncommon in *the nares*. Some of them are indubitably formed in the lachrymal passages, whence they glide into the nostrils; such was, in all probability, the case with the little girl spoken of by Bartholinus, who forced small calculi from her nose. In other instances they manifestly originate in the nostrils themselves; this is especially certain when the nucleus of the mass consists of a foreign body. Thus Horn found a calculus in the nares, the nucleus of which was a cherry-stone. Grandoni removed from the left nostril of a woman, aged 32, a calculus formed of fragments of unequal sizes, weighing 76 grains, of a specific gravity of 1.4, without smell, and chemically constituted as follows: —

Phosphate of lime	55.0
Carbonate of ditto	18.0
Carbonate of magnesia	7.0
Organic matter with traces of iron	20.0
	100.0

In the largest of the fragments a grass seed was discovered.‡

(*d*) *Frontal sinus, calculi of.*—Several calculi of small size, consisting of phosphate of lime, carbonates of lime and magnesia, oxide of iron and soda in small quantity, and animal matter, were discharged from the *frontal sinus* of a woman, whose case will be found in a foreign journal.§

(*e*.) *Mouth, calculi of.* — The interior of *the mouth* may become the seat of calculous formation. Schenk, Echold, and Bartholinus relate cases of its occurrence in connection with the mucous membrane of the palate; Kruger describes a mass of ashen colour, hard, round,

* Græfe and Walther's Journal, Bd. x. S. 597. 1827.

† Löwendardt, Brit. and For. Med. Rev. vol. xi. p. 233.

‡ Brit. and For. Med. Rev. vol. xi. p. 238.

§ Gaz. Méd. de Paris, t. 1. No. 2.

and very light, thrown off from an ulcer in the palate. Otto * knew a person in whom, during an atonic attack of gout, the whole mouth, throat, and gullet were largely covered with a whitish mucus [diphtheritic deposit?], which contained a large quantity of phosphate of lime.

(*f*.) *Salivary calculi*.—The calculous accumulations met with not very unfrequently in connection with the salivary glands, are commonly regarded as depositions from the saliva, and may be generically termed ptyaliths (πτυαλον, saliva, and λιθος, a stone). But they are at the least depositions from saliva of *morbid* composition, for while they are essentially formed of phosphate of lime †, this salt scarcely exists in the healthy fluid, and indeed is not enumerated among its ingredients at all by either Berzelius, Graham, or Wright. It becomes, therefore, extremely probable that the excess of phosphate is generated through the influence of irritation of mucous membrane. Salivary calculi are of much more common occurrence in some of the lower animals (*e.g.* the horse, ass, and dog) than in the human subject.

The parotid gland is less frequently the seat of these products than the submaxillary and especially than the sublingual gland. Pölker extracted an encysted stalactiform calculus, 15 lines long, 9 broad, and weighing 120 grains, from the parotid, composed of phosphate of lime and animal matter. Breschet describes white calculi of scaly fracture, some of them crystallized in regular tetrahedra, and having a nucleus composed of a grain of oats, which were discovered in the *maxillary* glands of an elephant: here, in addition to phosphate of lime and animal matter, there was carbonate of lime. The affection called *ranula* is produced by obstruction of the ducts of the *sublingual gland* with calculous matter, which may form a single large mass, or be united into numerous minute ones. Chronic inflammation and abscess are the frequent results of such accumulations.

Of similar origin is the calculous matter which gathers round the teeth, commonly called tartar or odontoliths (οδων, a tooth, and λιθος, a stone). Two kinds of tartar have been distinguished by Duval ‡ : *a*, tartar of deep grey or even blackish colour, hard and compact, smooth on the surface, breaking almost like glass, and forming first on the root of the tooth, whence it spreads to the enamel; *b*, tartar of yellowish colour, less compact, friable, less smooth on the surface, forming on the enamel near the gums, whence it spreads to the crown in the majority of cases, but sometimes insinuates itself under the gums. Tartar appears first as a thin layer of slimy matter, which hardens; another layer is then deposited, hardens in its turn, and so on. It accumulates enormously in some instances, exceeds the tooth (to which it is often most firmly united) in size, and sometimes detrudes this from its socket. Berzelius found it composed of

Earthy phosphates	79.0
Undecomposed mucus...............	12.5
Peculiar salivary matter (Ptyalin)	1.0
Animal matter soluble in hydrochloric acid	7.5
	100.0

Buhlmann * has recently drawn attention to certain microscopical corpuscles, most frequently met with on teeth surrounded with tartar, yet not altogether absent from the cleanest. Originally described by Leeuwenhoeck, these bodies are of filiform shape, and found in three conditions: *a*, yellowish fibres usually collected into tufts; *b*, the same fibres broken and scattered among the epithelium and mucus; *c*, tufts of fibres mixed up with granular matter. They measure about 0.00006th of a Paris inch in breadth; from $\frac{1}{10}$th to $\frac{1}{2}$ a line in length: they are smooth, arched, or wavy, somewhat elastic and transparent and of yellowish white colour. The strongest nitric, sulphuric, and hydrochloric acids and caustic alkalies produce no change but that of rendering them a little more transparent: they are unaltered by heat. They are chiefly abundant at the junction of the tooth and gum. Infusoria (genera Vibrio and Monas) are also found in this substance.

(*g*.) The *tonsils* are not unfrequently the seat of phosphatic deposit. A calculus formed in one of the tonsils, of greyish white colour, containing an oval nucleus, was found by Wurzer to consist of phosphate of lime 63.8, carbonate of lime 16.7, animal matter 13.3, ptyalin with chlorides of sodium and potassium 7.1, iron and traces of manganese 0.1.†

(*h*.) The *pharynx* and *œsophagus* have both been, though in extremely rare instances, the seat of calculous incrustations. Rivière and Bartholinus relate such cases.

(*i*.) *Gastro-intestinal calculi*.—The calculi discovered in the *intestinal canal* agree, as regards such saline materials as enter into their composition, in being essentially formed of earthy phosphates, especially that of lime. They may, however, be wholly free from saline matter.

Intestinal calculi are generally few in number, unless when of biliary origin: as many as thirty, however, were found in the stomach by Bilguer. Their size varies remarkably, from that of a nut to a mass larger than the clenched hand: their weight varies proportionally,—they have been known to weigh a pound and a half, two, and even four pounds. Their specific gravity is low, varying from 1000 to 1400. Their shape is irregularly rounded, the irregularity being greatest in the largest masses, and, like biliary calculi, they affect their own forms mutually by lateral pressure. They occur in all parts of the intestinal tract, but are most

* Patholog. Anat. by South, p. 103.

† Poggiale (Journ. de Pharmacie, p. 337, 1839) found so much as 94 per 100 of this salt.

‡ Bull. de la Faculté de Méd. 1815, No. 7.

* Müller's Archiv., H. iv. S. 442, 1840.

† See also Schütz, Caspar's Wochenscrift, No. 45, 1838.

common in the cœcum, large intestines, and stomach, and in rare instances have been discharged by the mouth.

There is a very obvious distinction between intestinal calculi, seized by almost all writers on the subject, in regard of their origin: (1.) some originate elsewhere, and make their way into the alimentary canal; (2.) others are the result of the deposition within the intestines of certain materials around some substance acting as a nucleus, itself either introduced from without or from some other part of the system; (3.) others are wholly formed in the alimentary canal.

(1.) *a.* Biliary calculi, to be presently described, form the great majority of those belonging to the first class. They present precisely the same characters as while still in connection with the biliary system. *b.* Calculi sometimes pass into the intestine from the urinary passages. Dr. Marcet found a calculus, mainly composed of a mixture of phosphate of lime and triple phosphate, in the rectum of an infant with imperforate anus. A communication existed between the bladder and rectum.

(2.) Calculi belonging to the second class vary much in respect of their nucleus; the matter found in the intestine, constituting the cortex of the calculus, is generally composed of phosphates, applied in layers or not, and mixed or not with additions of the vegetable or other substance which served originally as the nucleus; the mass is solid and compact, or softer and more porous, and mixed with the mucous secretion of the bowel. The division into layers is sometimes very indistinctly marked; generally a slight difference of colour exists in the different strata. Yellowish brown is the most common hue.

The nucleus in this class of calculi may be animal, vegetable, or inorganic.

(*a.*) *Animal.* — Under the name of *egagropiles*, or *hair-balls*, have been described masses of not uncommon occurrence in the intestines of the lower animals (especially of calves), composed of hairs in their central part, in their outer parts of concrete animal and saline matter. The hairs forming the nucleus are swallowed by the animals when licking themselves. Laugier* has very carefully described a felty-looking mass of some size found in the human rectum, the cortex of which consisted of fæces, hydrochlorate of ammonia and lime, phosphate of lime, silica, and oxide of iron; the nucleus, prismatic in shape and covered immediately with a brown crust, consisted in its central part of gelatin, in its more external of blood. Probably, as has been suggested, the mass originated, in consequence of a vessel being wounded by a piece of bone, — blood being effused round this, and saline matters subsequently accumulated round both.

(*b.*) *Vegetable.* — Nuclei of vegetable matter are more common. In graminivorous animals intestinal calculi of this kind sometimes acquire vast size. In a horse (aged 17 years) a mass was found having a nucleus of oat-grains, and so huge as to measure 28 inches round, and weigh 19 pounds (Breschet). Laugier and Lassaigne, in a similar mass, collected round bits of straw, found the cortex composed of earthy phosphates. In the duodenum of the human subject Andral discovered a calculus of the size of a small egg, consisting of earthy-looking matter externally, and having a plum-stone for its nucleus.

But the most interesting calculus of this species is endemic in Scotland, and for its full history we are chiefly indebted to the investigations of Wollaston and Dr. Monro Tertius.* The vegetable substance acting as the nuclear basis of the mass (which looks like felt or coarse sand) is the husk of the oat-seed in fragments, along with the minute fibrils, forming a velvety mass at one end of the seed underneath the husk. The abundant use of oatmeal in North Britain, as an article of food, explains the frequent occurrence of these calculi among the population; they are said by Dr. Maclagan † to be growing less common, in consequence of the greater care now bestowed in the north in separating the husky matters in preparing grain for the market. The inorganic constituent associated with the vegetable fibrous matter is mainly phosphate of lime (20 per cent. in two specimens analyzed by Dr. Maclagan), associated with silica, evidently derived from the oat (6 and 4 per cent.).

(*c.*) *Inorganic.* Certain medicines, magnesia (Monro) and chalk especially, have occasionally collected into calculous masses in the large intestine of persons in the habit of swallowing large doses of either for a considerable time: the saline matter being hardened into a solid ball with mucus and fæcal matter. Crockelt ‡ relates the case of a child who swallowed a pin, and at the age of 18 voided per anum a calculus of spheroidal shape and earthy composition. The head and half the stem of the pin were enclosed in the mass. A piece of wood accidentally forced into the rectum has been known to form the nucleus for phosphatic deposition.§ Females who chew and swallow the ends of threads used in sewing, or indulge in the singular habit of eating their curling-papers (hysterical pica), occasionally become the subjects of intestinal calculi.

(3.) Calculi formed wholly in the digestive passages are comparatively rare. They may consist of fæces and inspissated secretions wholly (under which circumstances the name, calculus, is not in strictness applicable to them), or these may serve as a nucleus for the deposition of the ordinary phosphatic salts. White discovered, near the ilio-cœcal valve of a tuberculous subject, two masses (one weighing two, the other one and a-half pounds) com-

* Mém. de l'Acad. Roy. de Méd. t. i.

* Morbid Anatomy of the Human Gullet, &c. 1811.

† Lond. and Edinb. Month. Journ. of Med. Science. Sept. 1841.

‡ North American Journal, 1827.

§ Dahlankamp, Archives Gén. de Méd. t. xxiii.

posed of a nucleus of indurated fæces, and a cortex of saline matter arranged in layers. Oleaginous matters sometimes accumulate in the intestine in the form and of the consistence almost of calculi. A mass of this kind, voided by a young tuberculous female, and examined by M. Lassaigne, was found to consist of

Acid fatty matter composed of	Stearin, Elain, Peculiar acid	74
Substance analogous to fibrin		21
Phosphate of lime.......................		4
Chloride of sodium......................		1
		100

These oleaginous formations will be presently further considered.

The oriental *bezoard*, a resinous intestinal calculus, chiefly met with in certain species of goats and deer, appears (like ambergris in the whale) to be the result of morbid secretion from the bowels of the animal, and not to be composed (as was imagined by Vauquelin) of materials derived from its food. A very doubtful case of calculus occurring in the *human* intestine, with close resemblance to ambergris in its characters, has been published by Dr. Kennedy.*

We have lately examined some masses composed solely of fibrin, (Univ. Coll. Mus. presented by Dr. Rayner,) passed from the rectum after prolonged sufferings, simulating those of cancerous disease.

(*k*.) *Biliary*. (Gall stones, Choleliths). — Biliary calculi are found in every part of the system where the bile circulates, and even make their way occasionally into localities in which that fluid is not naturally found. Most common in the gall-bladder, they are frequent in the larger ducts; far less rare than has been affirmed by some writers in the radicles of the hepatic duct, not uncommonly encountered in their transit through the different parts of the intestine (where it is possible they may be sometimes actually formed), they are very rarely seen in the stomach.

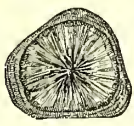
Biliary calculi vary in number from one to several hundreds and even thousands: 3,646 are said to have been shown by Fuschius from the gall-bladder of a certain gladiarius †; and Dr. Parry ‡ gives a case in which 2,654 were found in the same part. It is not uncommon to find one only, or two, three, or four; but observations are wanting as to the relative frequency of small and large collections. Their size varies as their numbers. When single or few in number, they are comparatively large, have been known to reach the bulk of a hen's egg §, but rarely, even when single, exceed a walnut in dimensions; when very numerous, they are sometimes scarcely larger than pins' heads, and some, of these small dimensions, may be associated with others of far greater bulk.

Their form likewise varies to a certain extent with their number. When single, the spherical, oval, or elongated shape predominates; when numerous, they press upon and mould each other into cubic, pentagonal, or polygonal figures, with obtuse and rounded angles.

Their most common colour is greenish yellow; but various shades of brown, green, dark or canary yellow, and even black or white, are observed. Their colour frequently varies in different parts of the mass; and the differences of hue may either correspond to the lamellæ of the calculus, or to the matters acting as the nucleus and the cortex respectively (the most common case), or be irregularly observable over the surface so as to produce a mottled appearance. Biliary calculi have a smooth surface and slightly unctuous feel.

When a biliary calculus is broken across, a distinction of nucleus and cortex is very commonly seen. Complete homogeneousness, without any lamellar or other obvious arrangement, is extremely rare. The cortical portion generally consists of dull-looking lamellæ arranged concentrically, but also striated transversely. A tendency to the alternating character of urinary calculi is sometimes visible: thus in the central point may appear a dark coloured and homogeneous matter in small quantity (bile pigment), and from this shining strata (cholosterin) radiate towards a cortex such as that above described (*fig.* 87.) The thickness of the cortex varies in different parts; though generally greatest at the angles of polygonal calculi (*fig.* 87), this is not always the case. In a few instances on record a foreign body (*e.g.* a piece of needle) has been found forming the nucleus of a biliary calculus; such cases are of singular rarity, however, and for obvious reasons.

Fig. 87.



Fractured surface of a biliary calculus.

The constituents of biliary calculi are cholesterin (the chief one) with other kinds of fat in small proportion, choleate of soda, bilifellinic acid or biliary resin mixed with bile pigment, epithelium, and mucus. In some cases the mass is almost wholly composed of colouring matter *; in others of biliary resin and modified colouring matter, with mere traces of cholesterin.† Berzelius describes a gall-stone composed principally of carbon. Von Bibra ‡ discovered 1.5 per cent. of alumina with iron, and 1.4 per cent. of carbonate of lime in a biliary calculus; the latter salt was also detected by Witting in considerable amount. A calculus analyzed by Bally and Henry ‡ consisted of carbonate of lime with traces of carbonate of magnesia 72.70, phosphate of lime 13.51, mucus with a little peroxide of iron and

* London Med. Chir. Journal, vol. iv.
† Morgagni de Sed. &c. Ep. 37, § 19.
‡ On Angina Pectoris, p. 240.
§ Saye, Journ. des Savans, Sept. 1697. Baillie, Morbid. Anat.

* Archiv. der Pharmacie, Bd. xli. S. 291.
† Simon, loc. cit. p. 470.
‡ Eod. loc.

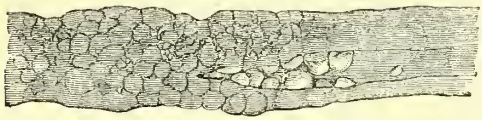
bile-pigment 10.81. Bertazzi* maintains copper to be a constant ingredient of biliary calculi, having found it in every one of fourteen specimens, apparently to an amount varying directly as the quantity of colouring matter present. Heller† confirms the statement of this chemist. Bertazzi failed in detecting copper in the bile collected from the gall-bladders of ten persons. In very rare instances calculi have been found composed of inspissated bile.

Mr. Taylor ‡ discovered a calculus in the collection of the College of Surgeons, presumed to be biliary, and composed of the stearate of lime. It floated in water, and had a lamellar structure ; the lamellæ being easily separable and alternately of white and reddish yellow colour. In the centre was a small cavity. The analysis, justifying the above view of its composition, is given in full. This rare description of calculus appears to signify a stage of transition from the common cases to those instances in which the biliary passages contain masses composed essentially of carbonate and phosphate of lime, especially of the former salt. Richter describes a case in which the liver contained a multitude of such bodies varying in size from a pea to a cherry. Matter of this kind is occasionally found coating the gall-bladder and ducts ; and in the interior of cysts in the substance of the organ. (Baillie and Zannini.)

(*l.*) *Pancreatic.* — Calculi of the pancreatic duct have been observed in rare instances by Matani, Eller, Biumi, Galeati, and others. Baillie found some as large as a hazel-nut, of white colour and irregular surface, which Wollaston § showed were composed of carbonate of lime.

Fig. 88. represents a portion of a dilated pancreatic duct, which contained an enormous number of small calculi (such as are seen within it in the sketch) of dull white colour, perfectly round, varying in size from that of a pin's head to that of a small pea, elastic and hard.

Fig. 88,



Pancreatic calculi, natural size. (*Univ. Coll. Mus.*)

Pancreatic calculi have not, as far as we are aware, been found in the intestine in transitu outwards.

(*m.*) *Seminal.* — Calculous masses have occasionally been detected in the vesiculæ seminales and ejaculatory ducts.‖ Collard de Martigny found some composed of mucus and coagulated albumen chiefly, with a small quantity of calcareous salts.* These calculi sometimes accumulate in vast numbers ; thus two hundred were discovered in the right vesicula seminalis of a man aged forty-five †; no symptom had occurred during life connected with the organ.

* Polli, Annali di Chemica ; Milano, Juglio, 1845
† Archiv. vol. ii. p. 228.
‡ Lond. and Edinb. Phil. Mag. 1840.
§ Pemberton, Diss. of the Abdom. Viscera, p. 68.
‖ Hartmann, De calc. in vesic. seminal. Erfurt, 1765.

(*n.*) *Mammary.* — The lactiferous ducts are occasionally the seat of minute calculous bodies ; Gooch, Haller, Reil, and others report cases of the kind. Morgagni alludes to their existence in the breast of a gouty person. The history of the case generally connects their production with the function of suckling, and sometimes with obstruction of the flow of milk.

(*o.*) *Vaginal and pudendal.* — Calcareous accumulations in these parts are not extremely rare. They originate in a deposition of phosphates around some foreign body; a pessary for example, or around a nucleus of thickened mucus accumulating either from habits of uncleanliness or from malposition of the uterus. Köhler discovered five large chalky-looking masses, weighing together more than seven ounces, in the vagina of a woman, aged forty, affected with prolapsus uteri.

(*p.*) *Uterine.* — The internal surface of the uterus is in rare instances found more or less extensively lined with, or studded with rounded masses of, saline matter of variable consistence. This condition has been observed in cases of deviation of axis of the uterus ; the saline matter is in all probability composed mainly of phosphate and carbonate of lime.

(B.) Concretions or Pseudo-calculi. — Concretions are masses composed of saline materials deposited in a pre-existing organic basis, — the former, as they increase, gradually encroach on and, as it were, dispossess the latter, until eventually, in many instances, all obvious traces of its existence have disappeared. The saline matters are commonly deposited punctatim ; and the organic basis, in which they accumulate may be non-stromal (as, for example, tuberculous matter, atheromatous matter, &c.), or stromal (as, for example, fibrous tumour, &c.) And, again, the natural textures (as, for instance, cellular tissue, tendon, &c. in the case of tophaceous concretions) ; the solid elements of the circulating fluid (as the fibrin of the blood in the case of phleboliths) ; and, lastly, various adventitious substances (as those mentioned above), may severally act the part of that organic basis.

(*a.*) *Elementary cell.* — Perhaps the simplest form of true concretion is that in which an epithelium-cell becomes coated or studded with saline material. We have seen this condition in the epithelium lining adventitious cysts, in the epithelium floating in pleuritic effusions, and occasionally in that discharged with the urine. The concretions, not very uncommonly found in the choroid plexus, consist of round cells coated with calcareous salts. Flakes of albuminous substance may some-

* Journ. de Chim. Méd. t. iii. p. 133.
† Archives de Médecine, Juin, 1831.

times be seen in the urine coated with saline matters ; but this is merely a rudely analogous condition to those previously mentioned.

(*b.*) *Fœtal* (petrifactions).—At the opposite extreme to cases in which a simple elementary cell becomes the depositary of calcareous matter, stand those remarkable instances in which an entire individual becomes more or less completely invested with a coating of such matter ; while subsequent desiccation of the tissues (with, very rarely, partial calcification of these) mummifies the entire frame.

(*c.*) *Placental.*—Calcareous concretions are of not uncommon occurrence in the human placenta. Hannover found them in large number in twenty of two hundred placentæ. They are of white colour, rounded or branched in shape, and composed of phosphate of lime ; generally seated on the uterine, rarely on the fœtal, surface, near the border. The age and constitution of the mother or of the child, separation of the placenta, and hæmorrhages, appear to Hannover to be without influence on their production.

(*d.*) *Vascular.*—*Arteries.*—(1.) *Parietal.*—There are few conditions more familiar to the observer than the calcareous deposition in the coats of arteries, long erroneously styled "ossification" of these tubes. The saline materials, giving the ossiform aspect to the deposition, assume four different forms: 1. That of a gritty looking substance sprinkled over the internal surface of the vessel; 2. That of patches of variable size and thickness, sometimes sufficiently extensive to convert a considerable tract of the vessel into an inflexible tube ; 3. that of small rounded or shapeless masses, protruding or not into the interior of the vessel; 4. that of prominent spiculæ ; when their anatomical constitution appears more allied than under other circumstances to that of bone.

Mr. Brande found these incrustations to consist of sixty-five and a half per cent. of phosphate of lime and the rest of animal matter. These proportions must of course vary in different cases: thus Scherer * found "ossified" arterial membrane composed of—

Organic matter............	7.292
Phosphate of lime	63.636
———— of magnesia..	10.909
Carbonate of lime.........	18.181

M. Bizot † has given a tabular view of the relative frequency with which different parts of the aorta become the seat of this condition ; and from this we learn with more precision than could be otherwise attained, that the points at which the different branches are given off are far the most frequently implicated ; and that the posterior surface of the thoracic and abdominal divisions of the vessel suffers more frequently than the anterior in the proportion of 11 to 1.

The precise seat of calcareous deposit, in respect of the coats of the tubes, has been made matter of much disputation. We have ourselves found that in the aorta the new matter is thrown out between the middle and internal coats, and in the vessels of the limbs either in this situation or in the actual substance of the middle coat ; — or, to use the language which the modern anatomy of arteries would require us to adopt, we should say that the saline matter is deposited in the aorta in the striated and longitudinal-fibrous tunics between the epithelial and circular-fibrous tunics; and also, in the arteries of the limbs, in the substance of the circular-fibrous and true elastic coats.

There are three kinds of deposit, of common occurrence in the arteries, set down by writers as the nidus in which saline accumulation may occur: these are the "atheromatous matter," the "white spot," and the "cartilaginous patch." The origin and nature of these matters require to be briefly examined.

The atheroma of the arteries and cardiac valves is a yellowish matter occurring in minute particles, hardly larger than grains of sand ; separate or clustered into small patches ; most abundant at the points where vessels are given off from the affected trunk ; obviously seated underneath a coating of epithelium, and even probably under the striated tunic of the artery, (as when an attempt is made to peel it away by raising these two coats, it is in part removed with them, and remains partially adherent to the deeper-seated tunics); and distinctly *unctuous* to the feel, when accumulated in any quantity. The substance is indeed of fatty nature. Gluge * found that "an enormous deposition of fat globules solely and alone constitutes this morbid state, and in fact even with the naked eye a remarkable similarity may be perceived between the atheromatous state and certain forms of fatty deposition in the liver." Mr. Gulliver † has independently ascertained the same fact, and illustrated his description by figures. ‡

The researches of M. Bizot have very clearly established that this atheromatous matter becomes, with the progress of things, the seat of one or other of two series of changes, terminating in the one instance in ulcerous softening, in the other in calcareous deposition. The stages of the ulcerous softening are four : in the first the yellow matter becomes slightly prominent on the surface of the vessel, and the superficial fibres of the "middle" tunic lose their natural consistence; in the second the internal membrane is raised into little eminences by the accumulation of a matter which is sometimes liquid and puriform-looking, sometimes floury and dry, and occasionally containing minute shining scales, some of

* Simon, loc. cit. p. 477.

† Mém. de la Société Méd. d'Observation, t. i.

* Anat. Micros. Untersuchungen, Erstes Heft, S. 130, 1838.

† Med. Chir. Transactions, vol. xxvi. p. 86, 1843.

‡ We have occasionally found plates of cholesterin in greater abundance than oil-globules, — a fact having an obvious connection with the established circumstance of the excess of cholesterin in the blood of old persons.

which have a white and silvery look (cholesterin). In the third stage depressions with a smooth surface, (except in the points where the lining tunic has undergone fissure for the evacuation of the matter described,) mark the previous seats of this matter. The fourth stage is distinguished by the disappearance of the lining membrane in the affected points, and hence by actual excavation. Neither suppuration nor injection attend the changes reviewed.

When the atheromatous matter undergoes the calcareous change, a hard but minute point commonly appears in its centre; this gradually increases, especially in breadth, the middle coat being earlier implicated than the lining tunic, which is occasionally covered with concrete fibrin. Eventually the lining coat is destroyed, and the concretion brought into contact with the blood; the middle coat rarely becomes affected through its entire thickness. The deposition may commence in a multitude of minute points simultaneously, whence the atheromatous matter acquires a gritty feel.

The white and cartilaginiform patches are not in any instance the nidus of the saline deposit, according to M. Bizot; at least he has never succeeded in tracing the early processes of deposition in those patches. Nothing, however, he admits is more frequent than the deposition of atheromatous and subsequently of calcareous matter *underneath* the "cartilaginous" patch, which is occasionally perforated by the calcareous substance, and an appearance produced easily explaining the current opinion that the patch in question is the original seat of the saline particles. We agree with M. Bizot that the "cartilaginous" patch is altered plastic matter exuded on the inner surface of the vessels. Mr. Gulliver has, it is true, discovered fat-globules and crystals of cholesterin in the "white patch" of vessels; but the circumstance appears explicable in the manner just referred to as resulting from the French author's inquiries.

In the arteries of the limbs calcareous deposition may likewise commence in the middle coat itself, which becomes harder and thinner as the disease advances.

It is important to observe that the close examination of calcareous plates through their various phases of development demonstrates, as we have seen, their independence of inflammation.

Calcareous deposition is remarkably dependent upon age. Bichat calculated that the arteries of seven of every ten persons beyond the age of sixty were thus affected; while its existence is extremely rare in early youth. Writers have indeed maintained the perfect immunity of the vessels of youthful subjects from this change: but Mr. Young found the temporal artery of a child fifteen months old converted into a calcareous cylinder; Otto* once discovered incipient ossification of the aorta in a girl of seventeen; Wilson met with a similar condition in a child three years old; Andral in a girl aged eight; and numerous other instances of the kind are recorded. Calcareous deposition is more common in vessels of a large than of a small calibre, and especially in the aorta; rarer in the upper than the lower extremities; it sometimes extends through the entire arterial system of the trunk and lower limbs, — we have before us the vessels of a subject in this condition, who died with gangrœna senilis.* Such disease never occurs, according to Otto, in the arteries of the thoracic and abdominal walls, and perhaps those of the alimentary canal and liver; and is, on the contrary, common in those of the pelvis, of the brain, of the thyroid gland, the heart, the spleen, the kidneys, &c. The pulmonary artery is, comparatively speaking, considered exempt from calcareous deposition: several instances, however, are referred to by Otto, in which it was more or less completely "ossified;" it is not unfrequently so where the right and left cavities of the heart communicate, (but here the vessel is placed in respect of its contained fluid in the state of an ordinary artery). Hope † attended a lady, aged 60, in whom the "pulmonary artery was found quite ossified where it plunged into the lungs;" and from our own records of cases we know that slight alteration is not very uncommon.

The close comparison of corresponding vessels on the two sides of the body has led M. Bizot to the discovery that not only the same vessels, but the same parts of these, are, with the rarest exceptions, affected with the same alterations of structure,—that a law of symmetry regulates the development of these. Upon this point much curious information will be found in M. Bizot's admirable essay.

Calcareous deposition is common in the arteries of syphilitic subjects, and of those who have taken mercury to excess. Much fanciful hypothesis has been indulged in respecting the influence of certain kinds of diet on its production.

This morbid state destroys the elasticity of the arteries, renders them fragile, and interferes with the circulation; we have known it lead to rupture of the aortic valves. The calcareous matter protruding more or less into the vessel affords a centre for the blood to coagulate around, and may lead to its complete obliteration, — a result which it would appear may be produced by mere thickening of the coats; in either case suspension of the circulation and gangrene are the results. "Ossification" of the coronary arteries of the heart has been met with in cases of angina pectoris (recently by ourselves) and of sudden death, — probably rather acting as the occasion, than the cause, of both.

(2.) *Central.* (*Arteroliths.*) — Calcareous concretions, free in the interior of the arteries, are as rare as the conditions which we have just described are common. Otto‡ saw in the Copenhagen Museum "a round stone as large as a pea," said to have been taken from the

* Patholog. Anat., by South, p. 333.

* Univ. Coll. Mus.

† Diseases of the Heart, 3rd ed., p. 589.

‡ Path. Anat., by South, p. 335.

spermatic artery; but he believes it to have probably been of venous origin. Eight loose stony concretions have, he observes, been met with in an aneurismal sac*; the largest of these was as big as a plum. Landerer has recently analyzed an aortic concretion, which contained 14 per 100 of uric acid.†

Veins. — Parietal concretions are as rare in the veins as common in the arteries; central concretions as frequent in the former as rare in the latter vessels.

(1.) *Parietal.* — These are in truth of extreme rarity in the veins. That they do occur, however, and with somewhat greater frequency than is admitted by speculative writers, is certain. An example of "ossification" of the coronary veins is related in the Ephem. Nat. Cur. Dec. iv. An. x. Obs. 175; Cruveilhier‡ once found the popliteal veins studded with ossifications similar to those existing in the accompanying arteries; not a few examples of "ossification" of the vena porta are on record§; Morgagni and Baillie found the vena cava inferior in a similar state, &c. In many cases of the kind there appears to have been calcification of the parts immediately adjoining the vessels.

The sort of antagonism existing between the arteries and veins, in respect of parietal concretions, has been referred by Bichat to difference of structure of the lining membrane in the two classes of vessel; by Bizot to the dissimilar properties of the blood circulating in them; by others, who regard the deposition as evidence of decay, to the greater activity and consequent earlier exhaustion of the arterial tubes. None of these notions are unopen to objection.

(2.) *Central.* — Central concretions in the veins (pheboliths, from φλεψ, a vein, and λιθος, a stone,) are generally of ovoid or rounded shape; vary in size from a pin's head to a pea and upwards, in rare instances attaining the bulk of a hazel-nut, and in weight average about a grain or a little more at most; are of low specific gravity; occur singly or in numbers varying from two to ten and upwards; are either perfectly free, or adherent to the internal surface of the vessel either directly or by means of a slender peduncle (these three conditions may be observed in the same vein); are smooth on the surface, and (whether partly sanguineous or wholly calcareous) invested with a delicate membrane of serous aspect.

These concretions are unquestionably by far more common in the veins of the pelvic viscera (the spermatic, the ovarian, the vesical, the hæmorrhoidal,) than in others. They are not unusual in the splenic veins, and have been met with in the renal, mesenteric, prostatic (thirty were found in the latter by Ehrmann ||), and pubic veins; they have been seen twice by Cloquet in the vena cava inferior. They occur sometimes in varices of the lower extremities*; Dupuytren found them in the anterior and posterior tibial veins; but they have not, so far as we are aware, been seen in the veins of the arms.

Gmelin † found them composed of

Animal matter	27.5
Phosphate of lime	53.5
Carbonate of lime	15.5
Magnesia and loss	3.5
	100.0

The part of the vein containing a phlebolith is sometimes much dilated, and eventually the vessel may become obliterated above and below the obstruction. Lobstein conjectures that the new formation with its investing portion of vein may be altogether separated from its connections; and, in the case of the hæmorrhoidal veins, passed by stool.

Hodgson supposed that these bodies were first formed external to the vessel, and subsequently made their way into its interior; Andral that their original seat was the substance of the walls of the vein. The occasional existence of a peduncle does not, as has been presumed, really warrant these notions; as it may no doubt be formed either of fibrin or of plastic matter (thrown out by the tunics from secondary inflammation) coated with epithelium. Besides, the absence of marks of rupture of the surface further confutes them. It was suspected by Cruveilhier‡, taught by Lobstein§, and proved by Carswell||, that phleboliths originate in clots in the interior of the vessels. The following is the series of changes observed:—stagnation occurs; a clot forms; loses its red colour; becomes concentrically stratiform; acquires fibrous consistence, and gradually grows calcareous and indurated, stratum by stratum, from the centre outwards, until the whole mass acquires almost stony hardness. Dr. John Reid¶ regards the process of induration as one "resembling the formation of osseous tissue in other parts of the body;" a view invalidated by the absence of true cartilaginous matrix, or of osseous texture at any period of the evolution of the bodies in question.

(*e.*) *Lymphatic and lacteal.*—Although it is possible that the extreme rarity with which the lymphatic and lacteal vessels have been found to contain calcareous matter may in part depend upon those vessels being seldom examined, yet it is certain that such condition is really singularly uncommon. Cheston Browne** refers to a case in which the entire thoracic duct from the receptaculum upwards was "ossified" and obliterated. J. D. Scherb††

* Biermayer, Mus. Anat. Path. p. 101, No. 360.
† Med. Gazette, July, 1847.
‡ Essai sur l'Anat. Path. t. i. p. 70.
§ Ruysch, Thes. Anat. viii. No. 58; Meckel Path. Anat. Bd. ii. Abth. ii. S. 190.
|| Compte Rendu des Trav. Anat. &c. p. 38. Strasb. 1827.

* Bouillaud, Rev. Méd. Avril, 1825.
† Tiedemann's Zeitschrift, Bd. iv. H. i. 1831.
‡ Essai, t. i. p. 71.
§ An. Path. t. i. p. 505.
|| Fascic. Anal. Tissues.
¶ Ed. Med. and Surg. Journ. No. 123.
** Phil. Trans. vol. lxx. p. 323, 1780.
†† De calculo in duc. thorac. 1729; Haller's Diss. Path.

has described a concretion found in the thoracic duct. The lymphatics of the small intestines have been found in this condition by Walther.*

The lymphatic glands, especially the bronchial and mesenteric, are, however, not unfrequently the seat of calcareous precipitation in points, patches, or through their entire substance; it chiefly occurs in connection with tuberculous disease.

(*f.*) *Serous and synovial cavities.* — These cavities occasionally contain calcareous productions, evidently produced by the deposition of saline matter in a pre-existing organic basis. This basis, commonly effused fibrin (when the concretion has been free from the moment the process of saline deposition commenced), has in other instances been the substance of fibrous tumours once attached beneath the serous membrane, and accidentally set free.

(*g.*) Similar bodies are occasionally found in connection with the *fibrous* membranes. Andral† describes a very interesting case of tumour of this kind attached to the tentorium cerebelli.

(*h.*) *Cerebral.* — A concretion taken from the brain analyzed by Lassaigne‡ was found to be composed almost wholly of fibrin, of a small quantity of cholesterin, and of 4 per cent. of phosphate and carbonate of lime — the evident, though rare, result of previous hæmorrhage. A concretion from the cerebellum, examined by Simon§, about the size of a nut, of irregular angular form, very solid, both internally and externally resembling a piece of bone, and *enveloped in a fine coriaceous capsule*, consisted principally of phosphate and carbonate of lime with a little cholesterin. A similar concretion analyzed by John consisted of 75 parts of phosphate of lime and magnesia, and 25 of animal matter; another examined by Morin was composed of cholesterin, coagulated albumen, and earthy phosphates.

(*i.*) *Uterine.* — Much confusion has arisen from want of accurate distinction of the different kinds of saline deposition occurring in the uterus. These kinds, we hold to be, three in number. 1. The internal mucous surface may be coated with phosphatic salts. 2. The parenchyma of the organ may contain "ossiform" (really calcareous) globular masses resulting from the deposition of saline matter in the interior of fibrous tumours. 3. The uterine tissue may be the seat of phosphatic accumulation around foreign bodies. These bodies may be either introduced (*a*) from without, or (*b*) enter the uterus from some other part of the genital system. (*a*) Of the former case Brugnatelli records a curious instance. A calculus weighing about two ounces, of rough surface, and composed of phosphate of lime, was removed from the uterus of a young peasant, and on division found to have a small piece of the tibia of a fowl for its nucleus, — broken off, no doubt, from the entire bone, which had been introduced per vaginam, for the purpose of inducing abortion. (*b*) Fragments of fœtus derived from extra uterine pregnancy, as also moles and hydatids, occasionally form the nucleus or basis of saline concretions.

The *Fallopian tubes*, too, sometimes contain calcareous concretions. Walther had in his possession a globular calculus of yellowish colour, a third of an inch in diameter, weighing ten grains, taken from the left Fallopian tube of a woman aged forty. It is extremely probable, though not proved by examination, that these masses are, in some instances at least, the remains of fibrous tumours.

(*k.*) *Pulmonary concretions.* — The pulmonary parenchyma is an extremely frequent seat of concretions. The basis, in which the saline material accumulates, is by far the most frequently tuberculous; more rarely the fibrinous substance of simple inflammatory exudation forms its nidus: numerous points of interest are connected with these kinds of concretions, and will be more fully referred to in the section on tubercle. Cancerous substance in the lung may become locally infiltrated with saline substances; we have not *known* such change to occur in blood effused in this parenchyma.

The appendages of the lung are likewise among the habitats of concretions. Fibrinous exudations in the pleura occasionally form the basis for simple saline precipitation; or less frequently of an ossification-process. The bronchi become in very rare instances more or less completely blocked up with solid concretions, the organic basis of which, in the majority of instances, is not improbably (but this point requires further investigation) that material holding a medium position between diphtheritic deposit and common inflammatory exudation matter, which constitutes the anatomical character of "plastic bronchitis." In a case observed by Gorup-Besanez*, such, however, could not have been the origin of the saline accumulation, — at least presuming the chemical analysis to have been correct. Here a coral-like "ossification" was found in the bronchi of a man aged forty-five, as thick as a crow's quill, and extending through the whole length and breadth of the lungs. It broke with a crack; whether it was hollow or not, we are left to conjecture. On analysis it furnished

Fatty matters and traces of soluble salts	17.17
Mucus	32.46
Phosphate and carbonate of lime, with traces of oxide of iron	50.37

(*l.*) *Arthritic.* — The substances termed tophi or gouty concretions belong to the present class. Variable in shape, rounded or tuberculated; of yellowish white or brownish red colour externally, internally white; varying in consistence from soft toughness to very considerable hardness; sometimes unctuous to the feel; and apparently enveloped in a

* Mém. de l'Acad. des Sciences de Berlin, 1786-87, p. 21.
† Cl. Méd. t. v. p. 8.
‡ Journal de Chim. Méd. t. i. p. 270.
§ Loc. cit. p. 474.

* Heller's Archiv. Feb. 1846, or Medical Times, 1846; also Tice, in Med. Chir. Trans. vol. xxvi.

delicate membrane; these productions form within the laminæ of the capsules of the joints of the hands and feet, sometimes in the surrounding cellular membrane, and least commonly in the tendons. Their substance has a chalky look on section.

Their chemical constitution was first made out by Fourcroy and Wollaston; most correctly by the latter. Urate of soda forms their main saline constituent; with this is associated urate of potash and lime in small quantity, chloride of sodium in good proportion, and animal matter.

A gouty calculus from the metacarpus of a man aged only twenty-two, examined by Lehmann, presented innumerable four-sided prisms, arranged in stellar groups, consisting of urate of soda. The composition was as follows: —

Urate of soda	52.12
Urate of lime	1.25
Chloride of sodium	9.84
Phosphate of lime	4.32
Cellular tissue	28.49
Water and loss	3.88

The abundance of *urate of soda* in these calculi is a very remarkable feature in their constitution; and points to the probability of that salt existing in the blood of gouty patients.

(*m.*) *Cutaneous.* — The natural secretion of the sebaceous glands may be retained within those sacs in consequence of accidental closure of their orifices. And if the saline materials predominate much over the organic, either as a fault of original secretion or from inspissation, a concretion is the result. Epithelium and fatty matters of various kinds are always associated with the saline materials. These saline materials, which vary much in their per-centage quantity, are mainly phosphate and carbonate of lime.

SUB-CLASS II. — ANIMALIZED PRECIPITATES.

The distinctive character of products of this sub-class is, that they are exuded ready formed from the vessels; when (ceasing to mix with, or precipitated from, the blood) they appear as "products" outside the vessels, they possess as much of the attributes of organization as they are ever destined to acquire. The elements composing them are organic; but these elements are either by nature incapable of forming structure, (as sugar, oils,) or circumstances deprive them of the power they naturally possess of developing a structure (as certain protein-compounds): they are distinctly non-plastic.

The animal substances enumerated, when exuded from the vessels, always form (what may be called) *potentially* the material of precipitates; but circumstances occasionally prevent the *actual* formation of these. The morbid process essentially consists in exudation (secretive or other) from the bloodvessels — this is the theoretical precipitation. It would be a needless refinement to make a subdivision of *actual precipitates* and non-precipitated *potential precipitates.*

§ I. PROTEIN-COMPOUNDS. — When occurring as actual precipitates, the protein-compounds appear as minute microscopical particles, amorphous or granular; they absorb readily the ioduretted solution of iodide of potassium, and become of yellowish brown colour; they are insoluble in æther, altered but not dissolved by acetic acid, insoluble in mineral acids, and dissolved by maceration in caustic alkalies.

(A.) *Albumen.*—Of the so-called protein-compounds albumen is by far the most frequently observed as an adventitious product belonging to the present division. It is either (*a*) thrown off with certain secretions (of which it forms no part in the natural state;) or (*b*) it is retained in a structureless or non-organizable condition.

(*a.*) *Albumen in the secretions.* — Of these the most important is the *urine.* This fluid, as discharged from the bladder, is found, in a considerable variety of local diseases or general derangements of the system, to be impregnated either temporarily or more or less permanently, either slightly or abundantly, with albumen.* The various conditions under which this impregnation occurs were classed several years ago by us in the following manner; the advance of knowledge has in the intervening period rendered scarcely any change necessary. M. Martin-Solon's term Albuminuria may be conveniently used to signify the discharge of albuminous urine generally; but cannot be logically used as a synonym of (nor even as a convertible term for) the affection known as "Bright's Disease."

Albuminuria may be caused by —

First: An unnatural state of the blood. Secondly: Morbid states of the genito-urinary organs, either functional or organic, and when organic, either causing albuminous impregnation during, or subsequently to, the act of secretion. *Thirdly: Accidental admixture of genital products. Fourthly: Some cause hitherto unestablished.* A few remarks on these various conditions are absolutely called for.

First: Albuminuria from an unnatural state of the blood. Dr. Blackall, in his work on dropsies, has related cases of scorbutus and petechiæ in which the urine was coagulable; but as the condition of the kidneys was not inquired into, the narratives are unsatisfactory. M. Rayer†, however, states that he has found the albumen and red corpuscles of the blood pass occasionally into the urine in cases of scurvy, purpura, and hæmorrhagic fevers; while the fibrin diminishes in the vessels, and the watery portion becomes infiltrated into the cellular tissue, or exhaled on membranous surfaces. Traces of albumen were discovered by Heller‡ in the urine of a girl aged nineteen,

* Some chemists believe that urine naturally contains albumen, though in proportion so small as not to be reached by existing means of analysis; among these chemists rank Henry, Chevalier, and Dumas, (Leçon sur la Chimie Statique des êtres organisés, p. 39.)

† Maladies des Reins, t. i.

‡ Archiv. für Chemie, Bd. i. S. 12.

independently of red corpuscles, in a case of purpura. In the worst forms of malignant hæmorrhagic fever, however, no trace of albumen *may* be discoverable, — a fact recently exemplified in our wards at University College Hospital. — The notion that purulent deposits may be carried off through the kidneys is one of long-established popularity among surgeons; Ambroise Paré, Desault, and others held the doctrine: the fact is, however, far from being established. M. Rayer has for some years sought in vain for pus in the urine of individuals, in whom the absorption of purulent depositions of various kinds was effected under his own immediate observation. An abundant precipitation of phosphates with mucus and epithelium will, as we have ourselves witnessed, sometimes produce an appearance most strangely like that of pus, — the microscope and the addition of a little acid readily settle the nature of the deposit. Pus may, however, actually appear in the urine in cases of secondary abscess from purulent impregnation of the blood; but it is then produced, we believe, in the renal structures themselves, and is not composed of the originally formed fluid translated (with its properties unaltered) through the circulating system into the renal passages. It is for this reason that the narratives of cases of "absorbed empyema" (with elimination of pus, in substance, through the kidneys,) are, without the test of actual examination of the kidneys, altogether unsatisfactory. — Cotunnius* endeavoured to explain the presence of albumen in the urine of a dropsical patient, whose anasarca was rapidly diminishing under the use of diuretics, by supposing it due to the direct passage of the serous fluid through the kidneys. But he had not established the absence of albumen from the urine, before diuresis set in; M. Rayer (as also we ourselves), avoiding this source of error, has failed in detecting albumen in urine, passed concomitantly with the disappearance of dropsical effusion, whenever the fluid had previously been free from that principle.

Secondly: Albuminuria from morbid states of the genito-urinary organs. (1. *Functional.*) On the presence of albumen in cases of *simple* hæmaturia it is only necessary to observe, that the albuminuria rarely persists for more than a few days after the discharge of blood-disks has ceased; concerning its appearance in diabetic urine, we shall presently have occasion to speak. (See SUGAR.)—The urine of healthy individuals may become albuminous for a short while (for instance, four-and-twenty hours,) after direct or indirect excitement of the urinary passages. We are not quite sure of being right in ascribing the action of certain articles of food and medicinal agents to such intermediate irritation of the kidneys; it is perhaps equally tenable that an altered condition of the blood is, in these cases, the direct cause of the excretion of albumen with the urine. Dr. Christison* "has occasionally known a temporary albuminous impregnation produced in healthy individuals by eating freely cheese, pastry, and such other indigestible articles as are known to have in general the effect of increasing the usual solid ingredients of the urine, and occasioning a large deposit of lithic acid and lithate of ammonia." We agree with M. Martin-Solon † that when such consequences follow, individual predisposition must be admitted to exist. Dr. Christison has repeatedly seen the same condition of the urine induced for a time (and we have ourselves had cognisance of the same fact) by the action of a cantharides blister, when it excited symptoms of renal irritation. — That hyperæmia of the kidney of the simple kind may produce albuminuria, was very strongly maintained by M. Martin-Solon, on the evidence of cases which wanted but the test of post-mortem examination to render them conclusive: the valuable experiments of Mr. Robinson give full warranty to the opinion. (2. *Organic.*)—It may be considered as yet undetermined clinically, whether the urine becomes albuminous in cases of simple nephritis unattended with any of the anatomical changes peculiar to "Bright's disease;" if it does so, the impregnation is not constant, and is slight in amount. ‡ — The connection of albuminuria with the disease of the kidney described by Dr. Bright is, on the contrary, after much disputation, thoroughly established. While the error of supposing mere albuminous impregnation pathognomonic of that affection is, on the one hand, perfectly understood; on the other, the great importance of permanent albuminous impregnation, as a sign of the disease, is recognised. We have never ourselves seen a case of Bright's disease in which the urine was permanently free from albumen §; but the amount to which it is present is, of course, extremely variable; we have frequently treated cases in which the coagulation was so complete, that not a single drop of fluid escaped, when the test-tube was turned upside down after ebullition. — On the various affections of the urinary passages causing impregnation subsequently to the act of secretion (*e.g.* pyelitis), it is unnecessary to dwell; of albuminuria depending on encephaloid disease of the urinary organs, we have spoken in another work.‖

Thirdly: Albuminuria from accidental admixture of genital products. The urine becomes impregnated with semen under a variety of circumstances. The secretion of the testes

* De Ischiade Nervosa Comment. Viennæ, 1770, p. 30.

* On granular Degeneration of the Kidneys, p. 36, 1839.

† De l'Albuminurie, 1838.

‡ Becquerel (Seméiologie des Urines) found a little albumen in the urine in one of five cases of simple nephritis.

§ Dr. Graves (Dublin Journal of Medical Science, No. lx.) maintains that the renal alteration may, however, exist without albumen appearing in the urine, — an idea to be explained probably, by the occasional temporary disappearance of that principle (as we have more than once seen) even in cases pretty rapidly tending to a fatal issue.

‖ The Nature and Treatment of Cancer, p. 386.

escapes into the urethra in certain cases of paralysis and in habitual spermatorrhœa; and when the bladder is evacuated shortly after coitus (more especially in persons having stricture of the urethra) its contents carry with them a certain quantity of seminal fluid. We doubt that the prostatic secretion alone (the fact has certainly not been proved) leads to distinct albuminuria. Leucorrhœal and catamenial discharges produce it.

Fourthly: Albuminuria from a doubtful cause. Cotunnius*, Cruickshank†, Nysten‡, Andral, Rayer, Martin-Solon, Becquerel, and we ourselves, have found that the urine may contain a variable quantity of albumen during the progress of acute diseases — a fact which is now matter of familiar clinical observation. M. Martin-Solon shows that the impregnation occurs in about $\frac{1}{11}$th of all cases; this observer at one time held that the occurrence was of "*critical*" signification, an opinion he has since correctly relinquished.— In certain chronic diseases, unattended with any organic alteration of the kidneys, the occasional occurrence of albuminuria has been positively established: in disease of the heart by Darwall §, Forget ||, and Martin-Solon; in bronchitis and disease of the intestines by the latter observer; in aneurism of the ventral aorta by Dr. Morrison ¶; in phthisis by Toulmouche **, and by ourselves, temporarily. Of the *habitual* occurrence of albumen in *gouty* urine, the evidence is insufficient. Becquerel found it in seven of eighteen cases of *acute* rheumatism, depending rather upon the acute type, than upon the nature, of the disease. — In the exanthemata, albuminuria depends on simple renal congestion (resulting from the inaction of the skin); or (especially in scarlatina) on the supervention of a form of "Bright's disease," characterized by abundant accumulation of epithelium in the tubules.

The *saliva* is another secretion which, containing albumen in extremely small quantity in the natural state (not more than 1.5 in 1000 parts), becomes apparently impregnated with that substance somewhat abundantly in certain morbid conditions. Simon †† found 7.77 per 1000 in the fluid discharged in ptyalism. However, the elaborate analyses of Dr. Wright ‡‡ show that this excess of albumen is not a constant phenomenon; in a case of ptyalism he found the albumen reach only 0.6 per 1000, and in three other forms of morbid saliva analyzed by him (fatty, sweet, and bilious), the quantity of albumen equalized the average in the fatty variety only.

The *sweat* has been found to contain albumen by Anselmino in a case of rheumatic fever. Stark asserts that albumen may be detected in this excretion in "gastric, putrid, and hectic diseases, and also on the approach of death, in consequence of the abnormal solution of the solid constituents." Simon * failed in detecting any certain indications of albumen in the sweat of a person in the colliquative stage of phthisis.

(*b.*) *Albumen retained.*—That granular particles of protein-basis, retained within the tissues, are some of them albuminous, seems a very admissible proposition. The non-plastic protein-substance infiltrating the kidney in certain forms of Bright's disease, for example, is albuminous rather than fibrinous in all probability. But the difficulty of positively assigning their species to protein-compounds, especially under such circumstances, is sufficiently well known. The mechanism of albumen-precipitation within the body must be of different character from that by which it is effected without the frame, — at least it is not easy to conceive how the agencies, chemical and physical, which are known to produce precipitation of albumen removed from vital influence, can come into play among the tissues.

Albumen appears in the retained and non-plastic state as an important element in the fluid of dropsies; to avoid repetition, we defer its consideration under these circumstances to Part II., where dropsical products are examined.

(B.) *Fibrin.* (*a.*) *In the secretions.*—That fibrin should occur in the urine, in association with the other elements of blood, is no more than must be expected in cases of hæmaturia. But it has of late years been found that fibrin sometimes occurs in solution in that excretion independently of any other constituent of the blood. Thus Nasse † "knew a Catholic priest who passed, particularly during the night, a large quantity of whitish urine, that coagulated spontaneously in from ten to fifteen minutes after leaving the bladder, and often indeed coagulated in the bladder itself. The patient experienced no debility. On analysis the urine was found to contain a large quantity of fibrin, but no blood-globules." There were also prismatic crystals of triple phosphate present. Zimmerman ‡ has particularly followed up this subject, and affirms he has discovered fibrin in the urine in endocarditis, pleuritis, pneumonia, bronchitis, rheumatic ophthalmia, periosteitis of the occiput, and erysipelas of the face. Urate of ammonia or uric acid was sometimes present. The fibrin, he presumes, appeared simply as an excretion, sufficient oxygen not having been taken up to decompose it into its organic forms. Zimmerman holds, that in cases of coagulable urine the coagulation will be found to be due to the presence of fibrin quite as often as of albumen, — a proposition which appears to us utterly inadmissible.

* Op. cit. p. 31.
† Rollo on Diabetes, p. 444.
‡ Récherches de Chim. et de Phys. Pathologiques, p. 253. 1811.
§ Cyclop. Pract. Med. art. Dropsy.
|| Gazette Médicale de Paris, vol. v. p. 609. (two cases.)
¶ Dub. Med. Journal, No. xxxvi. 1838.
** Gazette Méd. de Paris. Fevrier, 1839.
†† Op. cit. vol. ii. p. 10.
‡‡ Medical Times, or Der Speichel in Physiol. Diagnost. and Therap. Beziehung, 1844.

* Op. cit. vol. ii. p. 109.
† Brit. and For. Med. Review, vol. xx. p. 75.
‡ Zur Analysis und Synthesis der pseudo-plastischen Prozesse; or, Brit. and For. Rev. loc. cit.

(*b.*) *Fibrin retained.* — The majority of protein-precipitates are probably fibrinous. At least spontaneous coagulation (a quality belonging to them alone) is by far the most readily conceivable cause of precipitation under the circumstances now pointed at.

Fibrin occasionally occurs as a potential precipitate in the fluid of dropsies, a fact which will be further considered in Part II.

(C.) *Casein* occurs in combination with fat in so-called "milky" urine.

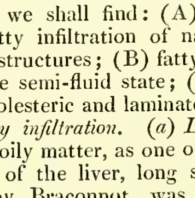
(D.) *Globulin* is practically unknown (as distinguishable from the other protein-compounds) in the present point of view: it probably forms the substance of some granular precipitates.

§ II. Fat.— Considered in respect of their ultimate physical elements, the varieties of fat (known to occur as morbid products) appear as adipose cells, free-fluid oil-globules (olein); solid fat granules (mainly margarin); groups of stellate crystals (margarin and margaric acid); rhomboidal plates (cholesterin). Fat may likewise be incorporated in such manner with the textures as to be only *chemically* discoverable,—a fact often lost sight of in the examination of morbid appearances: phosphuretted fat has thus (among other examples of the fact) been found in cancer. Of serolin as a new product nothing is known.

Unhealthy formation of fatty and oily substance is of almost perpetual occurrence. The fat produced is either similar (when viewed with the naked eye) to that naturally filling the cells of adipose tissue, or more or less completely dissimilar. In the *first* case the natural adipose structure is simply present in excess, whence arise *local or general obesity, fatty infiltration of parts, and lipomatous tumours*. In these conditions there is little more than hypertrophy or excessive secretion; and it is mainly in deference to usage that we shall, in another part of this article, describe lipoma as an adventitious product. In the *second* case the dissimilarity of the fatty material to natural fat, or the new situation in which it appears, gives it the character of adventitiousness. Here we shall find: (A) certain varieties of fatty infiltration of natural or of adventitious structures; (B) fatty matters excreted in the semi-fluid state; (C) encysted fats; (D) cholesteric and laminated fats.

(A.) *Fatty infiltration.* (*a*) *Liver.* — The existence of oily matter, as one of the natural constituents of the liver, long since proved chemically by Braconnot, was some years since established with the microscope, by

Fig. 89.



Nucleated particles from the healthy human liver. (After Bowman.)

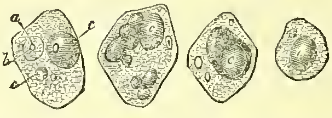
a, nuclei; *b*, nucleoli; *c*, fatty globules.

Gluge*, and more recently with greater precision by Mr. Bowman†, who displayed the position of the oil-globules in the elementary cells of the healthy organ. Now fatty infiltration may occur from superabundant deposition of the natural oil, or from that of oily matter differing from this in chemical constitution.

(1.) The liver, when "fatty," is increased, in some cases enormously, in size; its relations of shape remain unaltered. It is, by far the most frequently affected equally through its entire substance; but we have, in rare instances, seen the infiltration specially implicating islets of the organ; its colour is pale greenish yellow or faded leaf; sometimes but rarely studded with reddish points; its elasticity destroyed to such a degree that it pits on pressure; its consistence greatly diminished; its density decreased to so great an amount that slices have been known to float in water. Very rarely is this condition of the liver coexistent with other morbid changes in its substance; the vessels and ducts are unchanged in calibre and structure.

The fatty nature of the impregnation is sometimes obvious on the most superficial inspection; the hands and knives brought in contact with the tissue are greased; and if a thin slice be placed on paper and exposed to heat, the fatty matter melts abundantly, and oils the paper. Gluge was the first to show that these appearances depend upon the accumulation of a multitude of free fat globules, with a small quantity of yellowish granular matter, probably belonging to the colouring matter of the bile. Mr. Bowman discovered the precise *seat* of the morbid deposition to be the interior of the elementary liver-cells: "instead of containing a few minute scattered globules, the nucleated particles are gorged with large masses of it, which greatly augment their bulk, and more or less obscure their nuclei."

Fig. 90.



Nucleated particles from the liver affected with fatty degeneration. (After Bowman.)

a, nuclei; *b*, nucleoli; *c*, *c*, fatty globules.

We believe, however, with Mr. Gulliver‡, that in this morbid state fat accumulates "in the interlobular fissures and spaces, as described by Mr. Kiernan, or at least around the surface of the lobules, where it forms a distinct buff-coloured boundary to each of them. The ruddy-coloured hepatic lobules appear to diminish in size as the paler fatty substance increases. In a few instances it was principally seated in the centre of the lobules." Albers§ taught that the fat depo-

* Op. cit. Heft i. S. 126. 1838.
† Lancet, January, 1842.
‡ Med. Chir. Trans. vol. xxvi. p. 96.
§ Rust's Magazin, 1839.

sition chiefly takes place in the interlobular cellular membrane which has first undergone hypertrophy: he confounded cases of cirrhosis with true "fatty" change.

Vauquelin found that by exposing slices of fatty liver to a gentle heat, incapable of causing decomposition of animal matter, their composition, as the mean of several experiments, appeared the following: yellowish concrescible oil, 0.45; parenchyma, 0.19: moisture, 0.36. This fat unites with alkalies, and forms a soft soap with the usual properties. From a specimen immersed in boiling water by Dr. Bostock*, a quantity of oil exuded, rose to the surface, and, when the water cooled, was converted into a hard white substance, physically resembling tallow. It began to melt at 80°, and was completely fused at about 110°; in its chemical properties it generally resembled tallow.

Of the causes of this condition of the liver little is known. The fact of its frequent existence in France in phthisical subjects, already stated by Bayle and Laennec, was numerically proved by Louis.† This observer found fatty impregnation of the liver in 40 of 120 phthisical subjects, in 9 only of 230 persons dying of other affections; he also discovered that (uninfluenced by age) its proportional frequency in males and females is as 1 : 4. Andral‡, speculating upon these facts, suggests that, inasmuch as, in consequence of the morbid state of the lung, a sufficient quantity of hydrogen is not expelled in the form of pulmonary aqueous vapour, this element is separated in excess from the blood in the parenchyma of the liver, and there helps to form fatty matter. Mr. Bowman surmises, in a similar manner, that it arises from excess of carbon, (which it is the chief office of the liver to throw off from the system,) accumulating in consequence of imperfect respiration. But these conjectures are too exclusive in their bearing. Fatty liver occurs in non-phthisical subjects, whose respiration is naturally performed.§ Explanations of this class obviously fail to account for the unequal frequency of the fatty change in the phthisis of climates so closely similar as those of Paris and London; and leave unaccounted for the greater tendency of phthisical Frenchwomen than Frenchmen to the peculiar change.

(2.) The liver we have described is the "fatty liver," *per eminentiam*. But undue deposition of fat forms a not unimportant feature in other morbid states of the gland. In cirrhosis, for instance, as particularly shown by Gluge||, Hallmann¶, and Valentin**, accumulation of fat, either free or in vesicles, is as perceptible a character of the disease, as obliteration of the ultimate bile-radicles and blood-vessels and atrophy of the lobular structure. But we do not believe, with Gluge, either that this fat-deposition is the solitary element of the diseased state in cirrhosis; or that the "fatty" state of the liver already described (1) is the first stage of cirrhosis. On the other hand there can be no question that the true history of this common disease is, in respect of its fatty element at least, yet undetermined.

(3.) There exists a third form of fatty condition of liver, of which we have as yet but little experience, but which may not be passed over in silence. We have now some three or four times found minute crystals of cholesterin among the hepatic cells, (gathered together in sufficient quantity to render the nuclei of these obscure,) in portions of the gland, of pale fawn tint, flaccid, fragile, and rather greasy in look and feel. In one of these cases the gall-bladder was greatly distended with deep-coloured but quite fluid bile.

(*b.*) *Pancreas.*—The proper texture of this organ is sometimes infiltrated with fat, in such manner as to give it the aspect of being composed of that substance*,—a condition perfectly distinct from that of mere accumulation of fat between its lobules.

(*c.*) *Mamma.* — The acini of the mamma are said to be found by Dupuytren similarly affected; the observation, we think, requires repetition; certain it is, at least, that in fatty hypertrophy of the organ the acini continue distinguishable.

(*d.*) *Kidney.* — The kidney is subject to different species of fatty change, which have been confounded by writers under the general title of "fatty degeneration or transformation." *First:* in certain cases of *atrophy* of the renal textures dependent on cyst-formation, or on chronic pyelitis (either of calculous or simple inflammatory origin), abundant accumulation of fat takes place in the cellular tissue surrounding the kidney and underneath the capsule, and encroaches on its proper substance. *Secondly:* unnatural development of fat may take place amid the tissue of the kidney in connection with similar atrophy, sometimes perhaps as the cause, more frequently as the effect of this morbid change. *Thirdly:* the kidney, in very rare instances, acquires the colour and many of the properties of "fatty liver," greasing paper, &c. In a remarkable case recorded by M. Pascal †, the quantity of oil present was so considerable that it exuded from the organ under pressure, almost as from a sponge. No particular symptoms *appear* to have occurred in connection with this state; but its symptoms and minute anatomy both require investigation. *Fourthly:* M. Gluge ‡, some years since, taught that one variety of alteration, found in the kidneys of persons cut off with the symptoms of Bright's disease, was

* Bright's Hosp. Rep. vol. i. p. 114.

† De la Phthisie, p. 115, ed. 1.

‡ Anat. Pathol. t. ii. p. 598.

§ This condition of the liver is comparatively very rare, as we have elsewhere observed, (Physical Diagnosis of Diseases of the Lungs, p. 215.) in the phthisical population of this country. Of the numerous tuberculous subjects we have opened within the last four years, (1845,) not one presented this morbid state to any marked amount.

|| Op. cit.

¶ De cirrhosi hepatis. Berol. 1839.

** Repertorium, 1840.

* Lobstein, Anat. Path. pl. ix. fig. 1.

† Journal Hebdomad. 2e série, t. xii. p. 347. 1833.

‡ Op. cit. Zweites Heft, S. 130. 1841.

characterized by the deposition of fat-globules in the cortical substance. Of this alteration he recognises three degrees or stages. In the first, deposition of free fat-globules occurs in the cortical substance, unattended with obvious change in the tubuli or bloodvessels. In the second stage, deposition of yellowish altered fat-globules occurs within the tubuli of the cortical substance; the bloodvessels continue unaffected. In the third stage, deposition of peculiar altered fat-corpuscles takes place in rows in the site of the cortical tubuli; these tubuli being themselves destroyed in the same manner as the biliary ducts in the most advanced stage of cirrhosis of the liver. More recently Dr. Johnson * has given a character of precision to our knowledge of the relationship of fat-deposit to the morbid changes in Bright's disease. He finds: 1. that the epithelial cells of the healthy kidney contain oil to a variable amount; 2. that an excessive increase of this fat constitutes, primarily and essentially, Bright's disease; 3. that the pressure of this fat causes, by a simple mechanical process, the presence of blood and albumen in the urine, and atrophy of the kidney. We are here simply engaged in considering the fact of fat deposition in the kidney, and cannot digress into a discussion on the anatomy of Bright's disease. But we must venture to add that careful observation has shown and continues to show us, that the compound state, known as Bright's disease, (renal alteration, albuminuria, and dropsy, with the well-known train of secondary morbid conditions,) may exist without any undue deposit of fat in the kidney in any known form or condition.

(*e.*) *Testicle.* — The testis is liable to fatty destruction, the fat accumulating in the oil-globule form without and within the tubules.

(*f.*) *Lungs.*—Of fatty accumulation in the lungs little is known. We have never seen any condition cognizable by the naked eye, referrible to such alteration of structure; and have not, even with the microscope, discovered accumulated fat in tubercular lungs, except amid the tuberculous matter itself. Under these circumstances we have regarded the fat as appertaining rather to the tubercle *per se*, than to the diseased lung; nevertheless it has appeared to us that fat is associated in larger proportion with tubercle of the lung than with that of other organs.

M. N. Guillot has recently informed the French Institute † that, while the sum of fatty matters contained in the fœtal lungs varies from 10 to 18 per cent., it falls to 6 per cent. on the establishment of respiration. He further conceives he has ascertained that in all affections attended with temporary or permanent suppression of respiration in a greater or less extent of lung, the ratio of fat increases in the impermeable tissue. The natural ratio of fat to tissue being seldom more than as 10 : 100, it may change to even 50 : 100. Had the author made these deductions from the examination of phthisical lungs only, the fatty elements of tubercle might have been supposed to account for the excess of fat in the impermeable tissue; but he affirms that in pneumonia the same phenomenon occurs.

(*g.*) *Arteries and cardiac valves.* — Of these we have already spoken (p. 87).

(*h.*) *Muscles.* (1.) *Voluntary.* — In cases of continued inaction the muscles become infiltrated with fat; a fact readily ascertainable in those of paralyzed and of rachitic limbs. In old people the muscles of the calf of the leg and the sacro-lumbalis and longissimus dorsi frequently undergo this transformation. It is almost constantly observed in the muscles surrounding joints which are the seats of unreduced dislocation; and may be seen to accompany the atrophy produced by anchylosis or other causes, and in the case of old ulcers which have for a length of time interfered with motion. In scurvy the muscles sometimes undergo a similar change.

In a portion of muscle, appearing to the naked eye totally converted into fat, and weighing 13 drachms, $1\frac{1}{2}$ drachms were composed of muscle, 4 grains of gelatin, all the rest of fat.* The fact, thus chemically shown, that even in the most apparently perfect cases of disappearance of muscular substance, some of this remains, is fully demonstrable with the microscope also. Between and upon the muscular fibres and within the sarcolemma appear fat cells and free oil globules. Gluge has pointed out the existence of saline crystals in rachitic fatty muscles.

(2.) *Involuntary.*—Fatty destruction of the *heart's* substance may coexist or not with deposition of fat underneath the pericardium; and, as Bizot † has shown, has no connection with superabundance of subcutaneous fat: indeed this is true of the entire class of fatty changes, of which we are now speaking. The deposition of fat is most common on the right side of the organ, in the ventricle much more than the auricle.

In these cases there is but a superfluity of natural fat, which encroaches on, and renders soft and atrophous, the proper muscular texture. But there are certain forms of fatty change in which the muscular element itself is the seat of the primary disease, where a mottled dull yellowish aspect of certain portions of the organ is found to depend on accumulation of oil-globules within the sarcolemma.

(*i.*) *Tendon.* — Deposition of fat occurs within the sheath, and amid the primitive fibres of the tendons of paralyzed limbs.

(*k.*) *Nerves.*— The same statement applies to the nerves of such limbs. In cases of atrophy of the optic nerve, fat accumulates within the neurilemma.

(*l.*) *Bones.*— The bones become infiltrated

* Med. Chir. Transactions, vol. xxix. p. 1. 1846.

† Comptes Rendus, Juillet, 1847.

* Cruveilhier, Essai sur l'Anat. Pathol. t. i. p. 186. 1816.

† Mém. de la Soc. Méd. d'Observation, t. i. p. 353.

with fat in a peculiar form of atrophy * of their proper texture, which is often attended with fracture. The latter circumstance distinguishes such cases from those of ordinary osteomalacia, wherein (in addition to other characters not belonging to the present head, as, for instance, disappearance of their gelatin-element, Müller,) accumulation of free oil appears as an important character.

(*m.*) *Adventitious Products.* — Numerous adventitious products contain fat within their proper substance. Thus fat is a very frequent constituent of urinary calculi, and of various concretions,—for instance, the arterial species. In deposits, (as the typhous, tuberculous, and purulent,) it occurs occasionally in great abundance in the granule and oil-globule forms; and it forms a constituent of no mean importance (though an accidental one) of various growths. Thus in fibroma and osteoma the *total* absence of fat is unusual; and in cancer fatty matter occurs with such constancy as almost to take rank with its essential elements.

(B.) *Fatty matters excreted in the semi-fluid or fluid state.* — (*a.*) Fat does not exist naturally in appreciable quantity in the *urine;* in certain states of disease, however, oily matter is discharged in some quantities with the fluid. Simon and others have discovered fat in the urine of persons labouring under phthisis and tabes mesenterica; and it is commonly said to be of most frequent occurrence in diseases attended with rapid emaciation. We have ourselves in vain sought for it in numerous cases of phthisis at all stages, and consequently regard its presence as by no means constant. Dr. Elliotson relates the case of a female suffering from biliary calculi who passed about the third of an ounce of oil daily with her urine †: such cases are, however, not to be regarded without suspicion. Fat occurs, occasionally at least, in considerable proportion in the urine of females affected with puerperal fever.‡ Heller § found the same principle in three cases of herpes zoster. Fat also exists, associated with albumen, in some cases of Bright's disease, in saccharine diabetes, and in the so-called chylous urine: and there are three cases on record (by Canubio, Alibert, and Graves) in which the fluid was actually milky, containing fat and casein.

(*b.*) The *fæces* sometimes contain oily and tallowy-looking matters in large quantities. The circumstances under which intestinal discharge of this kind occurs, are not by any means fully understood. Peculiar functional derangements of the digestive process are sufficient, independently of organic disease, to produce discharge of the kind, whether per anum or through the mouth.* The fæces in diabetes mellitus are remarkable for their large proportion of fat. Dr. Percy found this principle amount to 16.16 per cent. of the dried fæces in a case where food of all kinds was taken.† May the alleged fact that grape-sugar is converted into butyric acid by bile, be considered to explain (or at least to illustrate) the occurrence of fat in these fæces? Some of it is probably derived from non-digested food.

(*c.*) The *saliva* occasionally contains "adventitious fatty matter and fatty acid," according to Dr. Wright ‡; he found so much as 3.9 of these principles in 1000 parts of one variety of morbid saliva.

(*d.*) The *sweat* is said to contain fat in the colliquative hectic state; but we know of no analysis satisfactorily proving the point. §

(C.) *Encysted fats.* — Fatty matters of different kinds occur in cysts. The chief varieties of these are *atheroma* (from αθηρα, *pultis*); *meliceris* (from *mel*, honey, and *cera*, wax); and *steatoma* (from στεαρ, fat); so called respectively from their pultaceous, honey-like, and suety appearance. The most common seats of atheromatous and meliceric cysts are the scalp and eyelids; the new matter sometimes accumulates in the sebaceous follicles.

One peculiarity of the fatty matter in meliceris and atheroma appears to be the absence of containing cells — the fat is free. Müller hence presumes that the cyst is formed of the thickened walls of an original single fat-cell, —apparently an unnecessary hypothesis. Besides the fat, there is a granular matter of albuminous nature in these masses.

Analyzed by Valentin ‖, the following was found to be the composition of this encysted fatty matter: —

Cholesterin	0.352
Elain and oleate of soda	3.216
Stearin	0.222
Albumen and potass; chloride of sodium and lime	1.572
Coagulated albumen	5.923
Water	88.715

Steatomatous matter is most commonly accumulated in the ovaries, between the vagina

* The frequent association of atrophy with fat-deposition in various organs (Carswell, Gluge) is as curious as it is positively established; but the mode of connection of the two phenomena has not been fully ascertained, and is probably not constantly uniform. It would appear rational to suppose that the fat-production acts most commonly as the cause (mechanically) of the atrophy with which it is found; but (to go no further) in certain atrophies of the kidney, the latter is, if not the cause, certainly the occasion of the former. It is a notable fact that in the organ which undergoes the process of senile atrophy to the highest amount — namely, the lung — coexistent fat is not found; at least, we have sought for it unsuccessfully with the microscope; it is true that M. Guillot's mode of investigation might point out fat that had otherwise eluded detection. Be this as it may, however, the same difficulty in determining the relationship of atrophy and other coexistent morbid changes (as, for instance, of serum-accumulation in atrophy of the convolutions of the brain in certain insane persons) is met with, as in the case of fat-deposition.

† Med. Chir. Trans. vol. xviii.

‡ Bouchardat, Journ. des Connaiss. Médicales, Août, 1843.

§ Simon's Chemistry, vol. ii. p. 320.

* See the author's work on Cancer, p. 324.

† Quoted in Simon, vol. ii. p. 378.

‡ Loc. cit.

§ See Simon, op. cit. vol. ii. p. 110.

‖ Repertorium, 1838, p. 307.

and rectum, and more rarely about the eyelids, scalp, neck, and prepuce. The matter itself is homogeneous, but differs in consistence in different parts of the cyst — it may be almost fluid in some. Dr. Lever * describes a cyst between the uterus and vagina which gave out a quantity of fluid matter, when punctured, that looked like "dripping" when cold. In ovarian cysts steatoma is frequently associated with hair.

(D.) *Cholesteric fats.*—Plates of cholesterin † are frequently found in the fluid of hydrocele and of cysts of the thyroid gland. Rayer ‡ found them in a cyst of the kidney, in a subject whose aorta contained several small tumours a little above the bifurcation, seated under the lining membrane, and composed in great part of cholesteric scales. § In a female who lately died in our wards with obstructed bowels from stricture of the rectum, a large cyst lying behind the right psoas muscle contained cholesterin in atheromatous-looking patches on the inner surface of its wall: here it was undergoing calcification.

Cholesterin has been found in scales among pus of an abscess near a carious tooth ||, and of an abscess near an anchylosed joint.¶ In such cases it disappears from the secreted matters before suppuration ceases.

Cholesterin occurs occasionally in various morbid growths,—for example, in the different varieties of cancer.

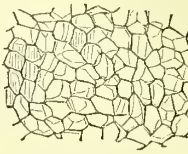
Closely allied to (if not sometimes identical with) cholesterin in chemical constitution, is a fatty product, for which the name of *cholesteatoma* has recently been proposed by Müller. This substance occurs in the forms of (1) *tumours*; (2) *granules*; (3) *patches*; (4) *scales*.

(1). *Tumours* composed of this material are commonly of the consistence of tallow; firmer than the brain when found in that organ. They are not lobulated, but frequently mammillated on the surface; uneven, with a general tendency to roundness; surrounded with a capsule of delicate fibrous structure; varying in size from a walnut to the clenched fist and upwards. Of sixteen recorded cases the brain was the seat of the tumour in seven; the bones in three; the utero-rectal cellular tissue in two; subcutaneous cysts in three; a large cysto-sarcoma of the breast in one.

The interior of the mass has a shining white and semi-transparent aspect, either generally or in some spots only, while in others the white colour is dull. Müller found that the substance shrinks and becomes yellowish by desiccation. All who have observed it describe it as composed of delicate laminæ, for the most part arranged concentrically, and easily separated: it is completely extra-vascular.

The laminæ and the matter interposed between them possess different structures. (*a.*) The laminæ consist of superimposed strata of cells, rendered pentagonal, hexagonal, or polygonal, by lateral mutual pressure, resembling, except in size (they are only half as large, averaging a diameter of .00081 of an inch), the cells of sheep's fat (*fig.* 91); easily

Fig. 91.



Polygonal cells of cholesteatoma magnified 290 *times.* (After Müller.)

separated from each other, transparent and pale; possessing neither nucleus nor central granules, and admitted to be hollow, rather from the analogy of sheep's fat, than proved to be so by observation. The substance forming the cells is distinct in its nature from fat, as it is neither dissolved nor deprived of its laminated appearance by boiling alcohol. (*b.*) The inter-laminar matter consists of crystals *tabular* and *lamellar*. The *tabular* are in greatest abundance; generally short, broad, and rectangular, but frequently narrow and riband-like, and probably composed of pure cholesterin (which appears under the microscope in the form of rhombic tables), as acids and alkalies do not affect them.

The *lamellar* crystals look like aciculæ of stearin from their being gathered into bundles; but when deposited from their æthereal secretion they are distinctly lamellar, and pointed at both ends.

(2.) *Granules.* — We agree with Müller in believing that the pearly looking globules described by Cruveilhier in a cancerous growth of the testicle * were very probably composed of cholesteatomatous matter.

(3.) *Patches.*—Dupuytren observed patches of this substance on the surface of a urinary fistula; Müller a stratum of it covering a cancerous ulcer of the mamma.

(4.) *Scales.*—The fluid of hydrocele and of tumours of the thyroid gland frequently contains scales of a pearly looking matter, sometimes collected abundantly at the most dependent part of the cavity. This matter, commonly believed to consist of cholesterin, is not always so composed. Dr. Bostock † found it essentially different from adipocere and from cholesterin, not soluble in water or in alcohol, but partially so in æther, and incapable of saponification by potash. Müller found the alcoholic or æthereal solution of the tuberiform variety yielded no oil on evaporation, but a fine granular fat, probably stearin, with lanceolate lamellar crystals,

* Med. Chir. Trans. vol. xxiii.

† Becquerel and Rodier affirm that the proportion of cholesterin in the blood increases in persons of both sexes from the age of forty to fifty: hence, perhaps, the greater frequency of separation of this fat in old people.

‡ Maladies des Reins, t. iii. p. 541.

§ See also Christison, Ed. Med. and Surg. Journ. vol. xxxii. p. 278.

|| Caventou, Journ. de Pharmacie, t. xi. p. 463. 1825.

¶ Nasse, Müller's Archiv, 1840, Heft. iii. S. 267.

* An. Path. livr. v. tab. i. fig. 2.

† Med. Chir. Trans. vol. xv. p. 158.

having convex edges converging to a point at either end, as before referred to.

In the peculiar softening of the vitreous humour called sparkling synchisis, the sparkling appearance at the bottom of the eye is said (Bouisson) to depend on the presence of molecules of cholesterin.*

The development of masses of cholesteatoma takes place, independently of blood-vessels in its substance, by successive generations of layers of cells, each layer being removed from the seat of its formation by that following, precisely after the model of epithelium. The cells being, as far as observation has gone, unprovided with nuclei, and containing no sub-cells in their interior, cannot be considered capable of producing new cells; the seat of true production therefore, as long as the mass continues to enlarge, remains unchanged to the last.

§ III. Sugar. — In a peculiar state of the system, the essential nature of which is as yet enveloped in obscurity, starch-sugar (identical in all properties with glucose†) accumulates in sufficient quantity in the blood to be easily detected in that fluid by chemical analysis. The same substance impregnates the secretions and excretions, — the urine, the fæces, the perspiration‡, the expectoration§, and (as is inferrible from certain experiments‖) the gastric juice.

In this disease (known as *saccharine diabetes*) the condition of the urine has always clinically attracted the chief attention. Not only is the sugar most easily discoverable in the urine, but this fluid is otherwise strikingly altered in qualities: its *specific gravity* ranges from 1028 to 1055 ¶; while its *amount* varies from two or three to seventeen pounds in the course of twenty-four hours. The connection of *albuminuria* with diabetes is matter of dispute. Cotunnius** observed long since that albumen occasionally occurs in diabetic-urine. Schönlein states, that the presence of sugar is preceded by that of albumen, the latter disappearing, while, with the advance of the disease, the former increases in quantity. Thénard and Dupuytren, observing coagulability of the urine occur in cases, where the fluid had been excessively abundant and saccharine, regard albuminuria as of favourable augury. M. Rayer†† has frequently known the change (as might be expected) announce coming dropsy. *Fat* sometimes exists in sufficient quantity in diabetic urine to render it milky-looking.‡‡ The once popular idea that sugar takes the place of *urea* in the urine has been set aside by Mr. M'Gregor's investigations, which show that the daily discharge of urea may throughout not only equal, but exceed, the healthy average. Deficiency of urea (which sometimes occurs) can only be regarded as accidental.

Various theories of the pathology of diabetes have been started. Those of the organic class (gastric, renal, &c.) have hitherto proved inadequate: the most accurate investigations have failed to establish any textural alteration antecedent in development to sugar-accumulation in the blood. Doctrines of the chemical class are in one point of view more entitled to consideration. Rollo originated these by ascribing the disease to mal-assimilation in the stomach — to decomposition of vegetable food into sugar through the influence of morbid gastric juice. Mr. M'Gregor's experiments proved the production of sugar in the stomach from amylaceous substances*, and thus gave the appearance of demonstration to Rollo's theory. Nor can more modern speculations be said to have done much else than to have shaped that theory to the principles of advancing chemistry. Of these speculations it appears well to notice two.

In the first of these the argument runs as follows:—In the natural state of the digestive process sugar is not evolved from starchy matters, the formation of that substance stopping at what may be called the dextrin stage: and further, the economy is doubly guarded against the passage of sugar, used as food, into the secretions: first, by a power on the part of the stomach of transforming sugar; and secondly, by a similar power on the part of the blood. Now in diabetes, it is assumed, both these powers are lost: swallowed sugar is not converted; and amylaceous matters are carried beyond the dextrin stage of transformation, and changed into sugar. But this doctrine of the chemistry of the disease appears to fall before the facts, that if much sugar be taken in a state of health, (as by persons indulging in punch to any amount,) the urine is distinctly found to contain sugar: nay, even under ordinary circumstances, sugar has been detected (Buchanan) in healthy blood soon after a meal.

The second theory, to which we shall refer, may be deduced from the following document, kindly supplied to us at our request by our colleague Professor Graham.

"The principal conclusions to which I have been led by a comparative examination of the

* Ranking's Retrospect, vol. vi. p. 286.

† Thénard, Rayer, and Bouchardat formerly maintained that diabetic urine sometimes contains an insipid sugar, independently of, or in addition to, the sweet variety; but later observations disprove the existence of any such body as the insipid sugar.

‡ Nasse, Rhein. Corr. Blatt. No. vi. 1842.

§ Francis, Lond. Med. Gaz. Feb. 12. 1847.

‖ Those of Mr. M'Gregor; vide note, next col.

¶ The specific gravity is in exceedingly rare cases not raised much above the healthy standard; Dr. Prout once found it even below this (1015).

** De Ischiade Nervosâ, p. 31. 1770.

†† Mal. des Reins, t. i. p. 151.

‡‡ Rayer, in L'Expérience, t. i. p. 664.

* Feeding a diabetic patient upon beef, Mr. M'Gregor found sugar in the contents of the stomach vomited immediately after a meal, and concluded (a notion accepted by Berzelius as the basis of his own theory) that the protein-compounds had been converted into sugar. The true explanation of the fact seems to be, that in this disease the blood contains so much more sugar than natural, that a certain share is thrown out with the gastric juice, and is of course discoverable immediately among vomited food. It is matter of doubt with the best chemists, whether sugar can be evolved from the much more closely allied substance, fat.

ingesta and digesta of diabetic patients, continued in two cases daily without interruption for several months, and for a few days at a time in several other cases, are as follows:—

"The quantity of saccharine matter found in the urine never exceeded the sugar and starch in the food. On the other hand, the sugar and starch of the food were accounted for in the urine to within one-fourth or one-fifth of the whole quantity. As there was always sugar besides in the fæces in a sensible, although not considerable, quantity, it appeared to follow that sugar and substances convertible in the stomach into sugar, are, in diabetic patients, nearly if not entirely indigestible; that is, they pass through the blood without being burned and thrown off in the form of carbonic acid and water, as they are in a healthy state. The idea of any portion of the saccharine matter found in the urine being formed from the protein or azotized portion of the food was entirely excluded.

"The proportion of sugar in the urine has a limit which it cannot exceed, but which varies within a small range in different patients, about $4\frac{1}{2}$ per cent. being the usual maximum. The volume of the urine comes, therefore, to be entirely governed by the quantity of saccharine matter in the food.

"Although sugar escapes oxidation in the respiratory process of diabetic patients, alcohol is entirely consumed. On one occasion a diabetic patient swallowed twelve ounces of absolute alcohol, contained in a quart of whisky, within twenty-four hours, without a trace of it appearing in his urine or other excretions. Gum arabic also, taken as food to the extent of five or six ounces a-day, did not cause an increase of sugar in the urine, and was probably, therefore, digested. Both alcohol and gum are, like sugar, pure aliments of respiration.

"It is well known that in the air expired by man, the proportion between the volume of carbonic acid found and oxygen deficient is remarkably uniform, and indicates that an excess of oxygen, nearly constant in amount, is consumed above what is represented by the carbonic acid, due of course chiefly to the oxidation of hydrogen. An amylaceous diet, in which the only combustible element is carbon, tends to reduce this disproportion, while an animal diet increases it. I therefore expected to find a deficient proportion of carbonic acid in the expired air of a diabetic patient confined to an animal diet; but such was not the case; the proportion proved to be perfectly normal. This implies a considerable waste of azotized food,—that even the protein-compounds are only partially digested in the system of a diabetic patient. The assimilating power appears, indeed, to be generally deficient."

According to Mr. Graham, then, the disease is to be understood thus:—In consequence of deficient oxidation of sugar in the respiration-process, that substance (which in the natural state of things is burned off as quickly almost as it mixes with the circulating fluid) accumulates to a greater or less extent in the blood, and its elimination from this fluid is partially effected through the secretions, especially the urine. This is a most plausible and clear view of the chemical mechanism of *sugar-disease;* but a *quid ignotum*—the cause of the deficient oxidizing power—remains in the back-ground, mysterious and impenetrable.

Class II.—Plastic Products.

This class includes all products possessed of organized arrangement, whether their structure be of a rudimentary or advanced kind; we shall distinguish them by the term Formations. Formations are themselves separable into two very distinct sub-classes;—the one in which the formation depends for continued existence upon the immediate and direct access of nutritious matter from the blood of the parent organism (*Blastemal Formations*); the other in which the vitality of the formation is not dependent upon such direct access (*Germ-Formations* or *Parasites*). While the products referrible to these two sub-classes differ in their structural characters, in their properties, in their vital actions, and in their influence on the organism containing them, they are no less distinct in their mode of origin. Those belonging to the one sub-class originate in a *structureless fluid* or *blastema;* those belonging to the other spring from a *germ.* And the distinctive attributes of the two sub-classes may in the most concise manner be put thus:—

Sub-Class I.—Dependent existence; origin from a blastema.

Sub-Class II.—Independent existence; origin from a germ.

Sub-Class I.—Blastemal Formations.

The structureless fluid just referred to is termed *blastema* (from βλαστος, a germ) in consequence of its being the germinal material from which certain formations are evolved; and likewise *cytoblastema* (κυτος, a cell), because an essential process in that evolution is the generation of cells.

The source of this material, as of the formative material of the natural elements of the organism is none other than the circulating fluid—the blood.* But there are three possible forms in which the blood may be supposed to furnish the germinal material in question. First, the blood in substance may itself constitute blastema; secondly, some of the elements of the blood, unaltered in properties, may constitute blastema; and, thirdly, some of those elements altered in properties may constitute blastema.

Now, analogy is opposed to the admission of the *first* of these possible cases: there is no instance of a natural structure being evolved from the blood as a whole. But arguments founded on analogy are valueless, if at variance with the results of direct and satisfactory observation. As matter of experience, then, does blood in substance, unaltered in apparent physical properties, and either retained within

* Of the chyle and lymph, as suppliers of blastemal elements, nothing is known practically.

or extravasated from the vessels, ever act as a blastema for cell-evolution? John Hunter, as is well known, held that extravasated blood was capable of organization (by which term he meant vascularization); but his statements do not by any means prove that the masses, assumed by him to be simple coagula, were not in point of fact more or less extensively mixed with coagulable lymph, or inflammation-exudation. Others have, however, endeavoured to give support and greater precision to the views of Hunter. Mr. Dalrymple*, some time since examining a coagulum (injected by Mr. Busk) seated between the tibia and its periosteum in a scorbutic patient, found its substance permeated by vessels, which he judged to be of new formation. The form, mode of arrangement, and general characters of these vessels, (as we have ourselves seen,) seem to justify the idea that they are really new formations; but no proof that exudation-blastema may not have been present amid the extravasated blood is adduced by their describer. More recently, Mr. Dalrymple†, not content with ascertaining the fact of vascularization of scorbutic coagula, has succeeded in tracing the progress of cell-development in the substance of such coagula. But if vascularization existed, the humbler grade of organization, signified by cell-production, was to be expected; and the new observations of Mr. Dalrymple do not remove the objection which in this point of view may be made to the old. Still these observations show very satisfactorily that the presence of blood in substance will not prevent the occurrence of cell-evolution and of vascularization, when the other conditions of its accomplishment exist.‡ In describing HÆMATOMATA, further on, we shall have occasion to return to this question; the reader may refer also to our observations on Softened Fibrin in the article on PUS.

Secondly, the blood-elements comprised under the title of liquor sanguinis, *slightly* modified in their relations of quantity and in their vital tendencies, are capable of constituting morbid blastema. By changes, such as these, is educed from the blood the fluid called coagulable lymph, the nature of which will hereafter be more fully considered.

Thirdly, certain elements of the blood, more or less *deeply* modified in essential properties, form the most common species of blastema. And what is the nature of the modification referred to? Is it physical, chemical, or simply potential?

(*a*.) As far as observation goes, the modification is not of *physical* character. Formations the most various (just as natural textures the most various) spring from blastemata having the same physical qualities.

(*b*.) Of the *chemical* constitution of blastemata at the moment of production, nothing is known from actual experiment; but that it is (setting aside its saline ingredients) albumino-fibrinous may be admitted as matter of inference from the source and mode of its production.

* Med. Chir. Trans. vol. xxiii. p. 205. 1840.

† Med. Chir. Trans. vol. xxvii. p. 70. 1844.

‡ See the author's work on Cancer, p. 51.

Scarcely, however, have these blastemata become the seat of cell-evolution than, as is fully established, their chemical composition varies very materially; while the resulting mass is in some instances essentially composed of albumino-fibrinous elements, in others it is of fatty nature; in yet others it yields gelatin. The question then arises whether the chemical difference detected in any two given *morbid formations* has existed in their blastemal fluid *ab origine*, or been effected in connection with the process of cell-germination. In the absence of direct information on the point, it is natural to apply for its elucidation to the phenomena of healthy nutrition. Now, in the evolution of the *natural tissues*, compounds of various chemical constitutions spring into existence in close juxtaposition from the same blastemal fluid. And this diversity of chemical combination is certainly connected in some way or other with the presence of cells: for one of these vesicles (while the *walls* of all are, as far as is known, of protein-basis) may be shown to have fat for its *contents*, another pigment, another a protein-compound, &c.; whereas, previously to the occurrence of cell-evolution, no such chemical distinctions could be established within the blastema. Chemical changes and cell-evolution are then connected; but in what manner? Conceivably in one or other of two ways: the development of cells may be (1) a mere coincidence with the generation of new chemical compounds, or (2) it may be its cause. 1. That it is a mere coincidence; in other words, that the cells are passive, and the blastema itself *alone* active in the chemical changes, cannot be admitted; all analogy is against it. Thus the importance of yeast-cells in the phenomena of fermentation is too obvious to be denied even by those, who refuse to accept the view of Schwann that those phenomena cannot occur at all in fermentable matters, unless through the influence of cells. 2. Cell-action then must have *some* influence as the cause of the chemical changes, and may by possibility be their (α) *sole* or (β) their *partial* cause.

(α) Supposing the cells the sole agents, we must admit that their solid constituents (wall and nucleus) in virtue of an inherent faculty (the so-called metabolic force) form new compounds out of the homogeneous matter surrounding them, this matter being chemically passive in the changes occurring. This was Schwann's view, and he grounded it on the analogy of the alleged necessity for the presence of cells as a condition *sine qua non* of fermentation in fermentable matters. But, as Henle has urged, the influence of cells is here exaggerated; cases are not wanting in which organic matters undergo chemical change through the sole agency of heat or acids, independently of the evolution of cells. And, it may be added, that in the progress of some fermentations, yeast-cells not only do not germinate, but actually disappear, as in the instance of a fermenting solution of pure sugar. (β) It would appear probable, then,

for this reason that chemical change is in some measure worked out by (and, inferentially, that chemical differences exist *ab origine* in) blastemata themselves; but, even thus, the cells must have an influence secondary only in time, not in importance. Like all membranes placed between fluids of different nature (the surrounding fluid and that contained within them), the cell-wall must be the seat of endosmosis and exosmosis, and the chemical result must be regulated, on the part of the cell, not only by the nature of membrane or cell-wall to be permeated, but by the nature of the fluid contents of the cell.

(*c.*) That the *potential* qualities of different blastemata differ is perfectly obvious; existences (such as cancer, pus, tubercle) must be formed from materials endowed with different vital tendencies. Concerning the nature and essence of this potential difference nothing is known with certainty. As respects the process by which its own special character is impressed on each blastema, and the locality in which that process is accomplished, three cases are possible: either the special character is given while the elements of the blastema are still circulating with the blood; or while those elements are undergoing filtration through the walls of the vessels; or at both these periods. Now, though it is probable that the filtration process exercises some influence of the kind under consideration, yet it is next to certain that the main influence is exercised on the blastemal elements within the vessels by the *constitutional state* of the individual, — that upon this constitutional state, and not upon any local process whatsoever, mainly depends the issue of a blastema, whether it shall be evolved, for instance, into cancer or fibrous tumour, pigment-cells or pus, fat or enchondroma.

The blood being the source from which blastema is derived, there are three distinct situations in which it may, *à priori*, be supposed to undergo evolution into structure: (*a.*) within the vessels: (*b.*) in the substance of the vascular walls: (*c.*) outside the vessels. Whether evolution does occur in all these situations requires to be examined into.

(*a.*) Certain adventitious formations are unquestionably found occasionally in the interior of the veins, and their presence can only be accounted for in one of two ways, either as the result of the absorption and subsequent germination of certain elements of growths pre-existing elsewhere, or of primary evolution of blastema which had never escaped from the vessels. There can be little doubt that in the great majority of cases intra-venous Formations are produced by evolution of *absorbed* elements; but it appears probable that they may sometimes spring from *retained* or *non-exuded* blastemal elements. It is true, the embryonic production of a fragment of natural tissue within the vessels is an anomaly of nutrition of which no example has, as far as we know, been witnessed; analogy is consequently opposed to the admission of a germinating force in non-exuded blastema. It is likewise true that, in respect of the simplest form of blastema (the inflammatory) escape from the vessels appears essential to evolution as a general fact; nevertheless, it is to be remembered, inflammation-products are evolved within the vessels in cases of arteritis and phlebitis, and in the healthy state epithelium is constantly being produced on the internal vascular surfaces. Hence the possibility of retained blastema germinating within the vessels must be, at least provisionally, conceded; and such germination may be imagined most readily to occur where peculiarities of texture interfere (as in structures of the erectile class) with the process of exudation.*

(*b.*) Nodules of adventitious structure have sometimes been met with in the actual substance of the parietes of the veins. The localization of these nodules becomes intelligible on the supposition either that blastema, furnished by the blood circulating in their interior, has germinated during the process of filtration through the vascular coats; or that the blastema was originally supplied by the vasa vasorum. The fact that the nodules in question have been principally met with in veins of a certain size (where exudation does not habitually occur) makes it probable that, in some cases at least, the vasa vasorum are the source of supply.

(*c.*) But both localities, so far considered, are rare, though possible, seats of germination; hence it follows directly that the common site of the phenomenon must be outside the vessels, and indirectly that the process of filtration through those tubes is commonly a necessary element in the generation of a blastema apt for evolution. Hence it is that *exudation fluid* has been employed as a synonym of blastema in general. Now the possible positions outside the vessels are: — the intervascular interstices of the various tissues and organs; the free (or sub-epithelial) surfaces, mucous, serous, and cutaneous; the surface (and, mediately, by imbibition, the substance) of the extra-vascular tissues; and, lastly, adventitious surfaces, produced by wounds and other agencies. Now observation (while it has decided that germination does actually occur in all of them) has proved the first-named of these situations to be by far the most common seat of the phenomenon.

In those cases, unfortunately restricted in number, in which observation has succeeded in establishing the characters of blastema (as in the instances of induration-blastema and pus-blastema) this fluid has been found homogeneous, almost perfectly transparent, slightly

* It is clear that what has been spoken of by writers as the "conversion of blood" into the substance of certain Adventitious Formations can be nothing more than an appearance produced by the evolution of primary blastema or of absorbed blastemal elements in the interstices of a coagulum: the idea of an actual change of either blood corpuscle into the cell of an Adventitious Formation is wholly inadmissible.

viscid, and free from solid particles of any kind. And the evolution of all kinds of blastema proceeds in the same manner, as far as hitherto ascertained, until the formation of cells is effected. The successive steps may in general terms be stated to be increase of viscidity, formation of granules, of nuclei, and of cells.* And these various steps cannot be accomplished except in blastema in contact with living animal structure, — a blastema loses its potentiality either by the death of the textures amid which it is evolved, or by its removal from among them. We place no confidence in the experiments upon which a statement of certain exceptions to this law has been founded. †

No matter what be the ultimate destiny of the blastema, the process of its evolution is conducted, then, on the same principle; but the development of cells sets a limit to this identity of process. The vital qualities of the cells differ, and affect the function and end of these, in three principal modes; and, according as each of these prevails in any given blastema, will the product generated (solid or semi-solid) present peculiar characters. These three modes of cell may be described as follows.

First, the cells once developed may be altogether inapt for life, incapable either of undergoing such changes in physical, chemical, and vital constitution as shall qualify them for sustaining a permanent existence, or of generating the elements of new cells previous to their own destruction. They are consequently acted upon physically and chemically by the surrounding materials: they are either dissolved by the fluid with which they are associated; or, disintegrated and broken down into non-productive granular matter, they lose all trace of the attributes of organization. Cells of this kind may be termed *evanescent* and *retrograding*.

Secondly, the cells may be deficient in the faculty of permanency requisite for the formation of tissue; while, on the other hand, they possess the power of generating the elements of new cells (or of causing indirectly the generation of those elements) previously to their own disappearance, — cells endowed in turn with a similar generative force. These cells consequently present the characters of the formative stages of evolution, never those of perfectly evolved structure. To this kind of cells the title *non-permanent* and *vegetative* may be applied.

Thirdly, the cells may possess an inherent force, qualifying them to pass through the necessary steps towards the formation of structure more or less closely resembling the natural tissues, and in this evolved condition they are destined permanently to remain. These cells appear likewise to be destitute of the power either of generating or of indirectly causing the generation of the elements of new cells similar to themselves; they may therefore be termed *permanent* and *non-vegetative* cells.

From cells of one or other of these three kinds all blastemal formations are produced. Formations produced from the evanescent cell are *non-stromal*, and may be termed *deposits;* those from the vegetative cell are *stromal*, and may be termed *growths;* those from the permanent cell are *stromal*, and may be termed *pseudo-tissues*.

Order I. — Deposits.

Deposits are deficient in the characters of texture; they possess neither permanent fibre, nor definite arrangement of parts, septa, nor loculi; and are insusceptible of vascularization. They tend to produce eliminatory action and ulceration in the seats they occupy; and are prone to appear, mainly through the influence of so-called "diathesis," in several parts of the frame simultaneously or consecutively. The substance of all deposits is *per se* non-inoculable; we say *all*, because, though the point has not been, to our knowledge, experimentally tested in regard of the typhous and diphtheritic species, there can be little doubt that the proposition applies to them as to the others. But certain varieties of one genus of deposit (pus) are, on the contrary, readily inoculable through the agency of certain associated principles called viruses (see Pus). In such cases, be it observed, the propagation of the disease in no wise depends on the cell of the fluid.

In the order Deposits (constituting transition products from the non-plastic protein-precipitates to formations of higher attributes) we place the following genera: *typhous*, *tuberculous*, *purulent*, *melanic*, and *diphtheritic* products.

§ 1. Typhous deposit.

In the form of continued fever anatomically characterized by alteration of structure in the glandular textures of the small intestine, a peculiar substance of new formation (as first accurately described by M. Louis*) is discovered in the cellular membrane between the mucous and muscular coats of the patches of agminated glands of Peyer. The proportion of cases of continued fever of intestinal type in which this deposit occurs, has been differently estimated from less than one third of the cases to nearly the entire number. We have found this matter homogeneous in aspect, of pinkish or yellowish hue (the former accidental), and from a sixth to a quarter of an inch thick; we have always seen it more or less firm and tenacious, and never succeeded in catching it in its earlier stage of fluid blastema. Examined under the microscope by Böhm † it appeared utterly destitute of

* The production of fibres without the intervention of a cell-stage (an exceptional phenomenon, if the entire system be taken in view) will find its place elsewhere.

† Helbert, de exanthematibus arte factis. Gött. 1844.

* Roederer and Wagler (De morbo mucoso, p. 332.) first *noticed* this substance thus: "ne semel tamen elevatos [folliculos coagmentatos] et materiâ mucosâ obscurè cinereâ repertos vidimus."

† Brit. and For. Med. Rev. vol. i. p. 524.

structure, and so it commonly is. But in some instances, in addition to granular matter lying in a structureless substance, remnants of cells may be detected, and, more rarely still, nucleated cells of unbroken outline, some larger, others smaller than the red blood-corpuscle. Epithelium cells are often accidentally present, as also oil globules.

That the main element of this material is of protein-basis may be inferred from its general properties. Buzzorini * gives its composition from direct analysis as follows, — fibrin, phosphate of lime, lactate and hydrochlorate of soda, and traces of other salts of the blood. Under the microscope acetic acid renders the basis more or less transparent; its effect on the cells seems to vary.

We have seen matter of similar character in the mesenteric glands; and we cannot affirm that the intestine and these glands are its sole seats, not having looked for it in other parts of the body of typhoid patients.

* Der Typhus, 1836, S. 87.

§ 2. TUBERCULOUS DEPOSIT, OR TUBERCLE.

Tubercle, when in that condition that its properties are most clearly marked, and when at that period of its development that no dissentient opinions are held as to its nature, possesses the following characters. It is an opaque substance of yellowish colour; sufficiently firm yet friable, of little tenacity, and resembling cheese very nearly in point of consistence; inelastic; without particular smell; accumulated in small masses varying in size from a pin's head to a hen's egg, of homogeneous aspect all over their divided surface; exhibiting no vessels; insoluble in water, and if mixed therewith quickly subsiding to the bottom. And these are the properties of a material which, in respect of its physiology, is characterized by its tendency to become soft after it has existed for a variable period in the condition of firmness, and to induce various changes in the natural textures with which it is connected, changes eventually effecting its own complete disintegration and elimination.

Nothing can be more true than that tubercle is homogeneous; but this may or may not be true of *a* tubercle. A tubercle of the brain is perfectly so; each particle is the counterpart of all others composing it, and for the simple reason that the natural structure, wherein the new matter has found a nidus, has been pushed aside in proportion as that matter has accumulated. A tubercle of the lung, again, may also upon rough inspection appear homogeneous; but if closely scrutinized with the naked eye, or, better, with a lens, it will be found that the section of the little body is marked by lines of a different tint and aspect from its general substance. This arises from the enclosure of some of the tissue of the organ by the accumulating tuberculous substance.

Tubercle may be deposited in isolated masses, or, it is said, be infiltrated through the stroma of the various tissues. (1.) When occurring in masses it is usually of tuberiform shape, and the mass has sprung either from a single centre of formation, or from the concrescence of several smaller tubercles formed in the close vicinity of each other. It has long been a subject of dispute whether tuberiform tubercle occurs in the encysted form. Laennec held the affirmative; and M. Louis follows on the same side. Dr. Carswell "feels perfectly satisfied that the term encysted, whether applied to pulmonary tubercle or to tubercle in any other organ, is almost always incorrect. In the lungs encysted tubercle is a deception, the distended walls of the air-cells having in all probability, in almost every case, been taken for cysts. In like manner the dilated bulbous extremities of the biliary system have been described as cysts of the liver containing tuberculous matter."* The evidence furnished by Laennec and M. Louis is defective; the latter observer never saw the presumed appearance in the lung but once, and no description is recorded from which the accuracy of the explanation offered may be ascertained.† On the other hand, Dr. Carswell's objection turns altogether upon his special notions concerning the almost limitation of tubercle to the mucous surfaces. We have ourselves never seen encysted tubercle in any structure of the body, if by the term be understood tubercle contained within a cyst, which has acted as its formative organ. But we have seen in very rare instances in the lung, and, comparatively speaking, somewhat more frequently in bone, tuberculous matter surrounded by a more or less complete membrane, strongly assimilable in properties to the pyogenic membrane of abscesses, and, like it, obviously formed consecutively to some at least of the matter it invested. Such we believe to be the key to the comprehension of "encysted tubercle," especially taken in conjunction with the fact that true abscesses in the lung have not unfrequently been mistaken for tuberculous accumulations. To the class of secondary cysts is also to be referred that species of membranous investment occasionally formed round tuberculous matter while undergoing a process of inspissation.

The *tuberiform* shape is so common in tuberculous masses that its cause has been made matter of inquiry. By some persons presumed to depend on a moulding faculty intrinsic in the tuberculous substance (an obviously absurd notion), it has been referred by Schroeder van der Kolk and Dr. Carswell to the influence of the surrounding parts. The latter observer well shows that, in point of fact, this shape is less common than has been maintained, and scarcely occurs except in the brain and cellular membrane, and under certain circumstances in the lung. *Straliform* deposition is that occurring on serous surfaces in layers; *ramiform*, that observed in the bronchi and biliary system.

* Illustrations of the Elementary Forms of Disease, Fascic. Tubercle.

† Louis on Phthisis, Walshe's Transl. Reprint, p. 426.

(2.) Infiltrated tubercle has been described principally in the lung, and is here said to exhibit two kinds of appearance; (*a*) the *grey*, and (*b*) the *gelatiniform*. (*a*) There are occasionally found in the lungs irregular masses of variable and, it may be, considerable size (five inches in diameter even) of greyish semi-transparent aspect, homogeneous, shining, and without distinct structure; such appearances are generally seen towards the apex of the organ, and may exist in very rare cases independently of any acknowledged form of tuberculous deposit; slices of texture thus affected sink in water, are moist on the surface, dense, and compact. In the midst of such masses it is sufficiently usual to discover a number of small specks of yellow opaque tuberculous matter; these increase in number and size, and thereby gradually cause the disappearance of the grey matter. Now it is admitted on all hands that the characters of this alleged tuberculous infiltration are extremely like those of chronic pneumonia; and in our mind it is extremely doubtful whether the morbid state be anything more than a particular form of that inflammation. M. Louis draws attention to the following points as distinctive of chronic pneumonic induration:—1. Instead of being transparent, the affected tissue is opaque; 2. instead of being homogeneous, it is traversed by thick white septa; 3. the indurated parts are more compact than in the presumed tuberculous infiltration. But in acknowledged chronic pneumonia all these characters are subject to a great variation in amount; and the formation of yellow tubercle proves nothing in either direction, as there is no reason why such formation should not occur in a tissue infiltrated with induration-matter. (*b*) Of the *gelatiniform* tuberculous infiltration of Laennec, it is sufficient to say that no doubt can be entertained as to the fact of his having described, under this name, infiltration of common exudation matter with excess of serosity, sanguineous or not. Tubercle does, however, occur in the endosteal texture of bone in the infiltrated form.

The microscopical constitution of yellow tubercle may be described as follows, at least according to the observations we have ourselves made. (1.) *Granular substance* exists in abundance in tuberculous matter; large masses of soft consistence sometimes consist almost solely of it; and, as the process of softening advances, it abounds likewise; when of well-defined characters and abundant, it constitutes a very distinctive element of tubercle. The granules are dark, of yellowish brown tint, heaped up in masses, varying in size from about 1-4th or 1-5th of that of the red blood corpuscle (say $\frac{1}{12000}$ or $\frac{1}{15000}$ of an inch) to the merest points. Some of them, undissolved by acids, alkalies, or ether, are of modified protein-basis; others, soluble in hot ether, are of fatty nature: the latter are sometimes, though rarely, absent altogether. (2.) *Cells.*—Cells, though probably always existent in tubercle at some stage of its development, are not always to be found, or to be found in very minute proportion only, in specimens examined. In some cases they apparently constitute the entire tuberculous mass. We have found them sometimes of circular form, and rather flattish; sometimes irregular in shape and with rounded angles, never caudate, and nearly averaging in size that of the white blood-corpuscle. They contain a variable number of granules scattered without order through their substance, but generally leaving a free circlet at the periphery. We have never seen a distinctly defined nucleus within them; acetic acid simply renders the cell-wall more transparent, and exhibits the granules more clearly. (3.) *Irregular particles.* Shapeless particles, flat, pale, and on an average of less size than the cells, are sometimes seen. These are probably, in part at least, the walls of disintegrating cells; whether they eventually go to form granular matter is a point open to inquiry, but appears to us probable. With these the substantial constituents of tubercle, are sometimes accidentally associated. (4.) *large fat globules;* (5.) *plates of cholesterin;* (6.) *amorphous saline particles;* (7.) *melanic cells and granules.*

Nothing having the attributes of a stroma can be detected in tuberculous matter; but a semi-transparent substance, more or less solid, slowly soluble in acetic acid, absolutely structureless and amorphous, holds its elements together. Neither does tubercle ever contain vessels of new formation; and the imprisonment by tuberculous deposit of natural capillary vessels, still pervious, is comparatively rare and accidental; there is a tendency, constant in action, and eventually irresistible, to obliteration of the vessels around and amid which the blastema of tubercle is thrown out. A new vascular system, we are aware, has been found to originate in the vicinity of tubercle; but this development takes place within common inflammatory exudation matter. In the same way there may be found on the confines of tuberculous matter compound granule-corpuscles, pus-corpuscles, with, of course, the ultimate elements of the tissues implicated.

In the same natural texture with such tuberculous matter as we have now described, are very frequently found certain small bodies varying in size from that of a pin's head to a very small pea, of greyish-white or greyish tint and glistening aspect. These bodies are known as the *semi-transparent grey granulation*; and their affinities to yellow tuberculous matter have been a theme of constant disputation from the period at which tubercle first became the subject of close study. While some regard them as products of common inflammation (Schroeder van der Kolk, Andral); while visionaries are found (Kuhn*) to maintain that their relationship is closest to the Nemazoa of Gaillou (a class of beings forming a link between vegetable and animal existences); while a reasoner habitually most cautious (Carswell) regards them in some situations — the lung — as an admixture of mucus and true

* Gaz. Méd. de Paris, t. ii. p. 342. 1834.

tubercular matter, in other situations as an admixture of the same matter and coagulable lymph; the majority of observers hold them to be actual tubercle in an early stage of development. The latter opinion under certain modifications, we believe, for reasons which will presently appear, to be the true one.

These bodies occur in different organs and textures in association with yellow tubercle; they are more or less transparent, and, though in their own substance of light greyish colour, their translucency sometimes gives them in appearance the tint of the circumjacent structure; their section exhibits a smooth and close surface; hard as cartilage almost in some instances, and invariably remarkable for firmness; in general outline seeming roundish, yet in reality of somewhat angular form; and adhering so closely to the adjoining tissues that they cannot be removed without particles of these, they have a striking tendency to accumulate in groups.

Now the motives for connecting this production pathologically with yellow tubercle, and regarding the one as a phasis of the other, are derived as well from (*a*) naked-eye observation and considerations of general pathology, as from (*b*) microscopical examination. (*a*) Common yellow tubercle appears in the substance of the grey granulation at a certain stage of its existence, and gradually (in the lungs and in bone for example) fills the entire space it had occupied. In the lungs the grey granulation follows the same topographical course as yellow tubercle; originating in the upper regions, it migrates downwards; and the quantity of the one, as of the other, is greatest at the apex.* Grey granulations are found mixed with yellow tubercle in various organs, and so rare is the development of the one without the other, that M. Louis † only encountered grey granulations without yellow tubercle five times, and the latter without the former once. The material composing the grey granulation also occurs in the form of shapeless masses, and when so deposited (as in the lungs and lymphatic glands) also becomes the seat of yellow tubercle. (*b*) Microscopically considered, the elements of the granulation prove the relationship of the two products. A hyaline substance, non-stromal, holds together cells, identical with those already described, mixed (sometimes) with melanic matter in small quantity, and the elementary fibres of the implicated tissue (doubtless the objects mistaken in the lung by Kuhn for vegetable filaments). The proper granular matter of tubercle alone is absent, or present in very minute proportion only. The disintegration and breaking up of the cell-structure, and the exudation, further, of blastema, which, incapable of furnishing cells, generates granules, cause the appearance of yellow opaque amid grey semi-transparent tubercle.

It appears, then, that the two conditions, grey and yellow, are stages of each other. But is this sequence necessary; must grey matter precede the yellow in the order of evolution? No: for in some textures, as the lymphatic glands, grey matter is very rare; in others, as the brain, it is not, as far as we know, ever seen, though yellow tubercle is not of very uncommon occurrence there in infancy; and, lastly, in the lungs, tubercles are sometimes found of the minutest conceivable size, yet yellow throughout their entire substance without the least grey appearance. It follows, then, that the ordinary first or grey stage may be to all seeming passed over,—an idea by no means repugnant to reason, inasmuch as such a state of things would naturally occur wherever a peculiarly low crasis of the system leads to primary production of granular matter in excess and unusually rapid disintegration of cells.

Another kind of granulation occurring in the lungs, first described by Bayle, and by him supposed to be composed of adventitious cartilage, has been by almost all writers confounded with the common grey production. This variety is, we believe ourselves justified in affirming, of great rarity; at least we have met with but one example of it—some years since at the Hospital for Consumption. In this instance the granulation was of round or oval form, as large as a good-sized pea (all present very uniformly so), of dull white colour, opaline without yellow points, present in moderate numbers, disseminated equably through all parts of both lungs, not grouped, but deposited solitarily, producing no visible change in the circumjacent texture, and unassociated with yellow or grey tubercles. Bayle, maintaining the obviously erroneous opinion, just stated, of their anatomical nature, connected these bodies pathologically with phthisis; Laennec regards them as a modification of the common grey granulation; our own opinion on the point is unformed.

Among the numerous published analyses of tubercle, we have for some years been in the habit of referring to that of Preuss * as at least the most elaborate in existence. According to the results of this analyst, one hundred parts of tuberculized pulmonary substance consisted of

Water	79.95
Tuberculous matter	13.52
Fibrous residue, vessels, bronchi, &c.	6.53

One hundred parts of the fibrous residue consisted of

Fat	4.13
Substances yielding gelatin by boiling	20.67
Substances yielding no gelatin by boiling	75.20

The tuberculous substance itself, without water, contained:

Substances soluble in hot alcohol only.

Cholesterin	4.94

In cold alcohol and not in water.

Oleate of soda	13.50

* In acute miliary tuberculization, however, the grey granulation, scattered equably through the various parts of the lung, is deposited in an isolated manner.

† On Phthisis, Transl. p. 2.

* Preuss, Dis. Inaug. Tuberc. Pulmon. Crudorum Analysis Chemica. Berol. 1835.

In cold alcohol and in water.

A peculiar substance (*Phymatin*)	
Chloride of sodium . . .	8.46
Lactate of soda . . .	
Sulphate of soda . . .	

In water but not in alcohol.

Casein	
Chloride of sodium . . .	7.90
Sulphate of soda . . .	
Phosphate of soda . . .	

Neither in alcohol nor in water.

Casein (altered by heat) . .	
Oxide of iron	
Phosphate of lime . . .	65.11
Carbonate of lime . . .	
Magnesia	
Sulphur	
	99.91

Phymatin (φυμα, a tubercle; like pyin, the discovery of Gueterbock,) is described as a peculiar extractive matter, not precipitated from its solution by extract of galls, very little by neutral acetate of lead and nitrate of silver, but, on the contrary, very copiously by basic acetate of lead; sulphate of copper gives no precipitate, according to Gueterbock; a white flocculent one, according to Preuss. The main protein-constituent of tubercle appears, from the above analysis, to be casein. But numerous chemists question the correctness of this analysis, precisely in respect of the casein; and it certainly appears proved that Preuss had not furnished sufficient evidence of the nature of the protein-compound contained in tubercle. Scherer* has endeavoured to establish the relations of this organic material to protein, and dwells upon the fact that according to the locality of the diseased product this may be theoretically formed by adding to or taking from protein a varying number of atoms of oxygen, hydrogen, and carbon. The formula of protein, as given by different chemists, it is to be remembered, varies, — its very existence is made matter of question; we are, therefore, unable to discover in what manner the chemistry of the formation of tubercle can be considered to be advanced, or to be likely at present to be advanced, by speculations of this class. The insignificance of such hypotheses becomes apparent, too, from the fact that some of the analyses of tubercle differ as much from others as these do from the analyses of cancer!

M. Boudet † finds, with respect to its organic constituent, that tubercle yields *albumen* and a matter analogous to *casein*, under the action of cold water, and is reducible to a substance having the characters of *fibrin*; he further discovers that casein, insoluble in crude tubercle, becomes soluble eventually through the development of alkali: a series of propositions more striking than satisfactory.

* Simon's Chemistry, vol. ii. p. 430. 1846.
† Bulletin de l'Acad. Royale de Médécine, t. ix. p. 1160.

Tubercle is insusceptible of growth, properly so called: it increases in size by accretion of new particles or by gradual coalescence of minute masses, at first separated from each other by appreciable intervals. In the lung the latter mode of enlargement is invariably observed, where the tubercle is of any size; hence the constancy of septa, as already referred to.

Tubercle, having subsisted for a variable time in the firm (or, as it is called, crude) state, tends to undergo either of the following changes:—(1.) to become invested by a cyst; (2.) to decay by a process known as softening.

(1.) In certain situations, more especially the bronchial and mesenteric glands and bones, tuberculous matter, undergoing gradual inspissation, occasionally becomes invested with a cyst (of fibrinous origin), which cuts it off from the surrounding textures, and renders it, comparatively speaking, innocuous.

(2.) When tuberculous matter has existed for a certain but variable period in the state of firmness or "crudity," it in the vast majority of cases softens. In this new state its physical characters are either very closely similar to those of thick deep-yellow pus, or (which is more common) it seems to consist of two materials, the one soft, friable, and caseiform, the other more or less watery and transparent, mixed together in variable proportions. Commencing by possibility at any part of the tubercle, this process commences more commonly towards the centre, or at least within the area of the tubercle, than on its confines.

The process of softening must either be of intrinsic or extrinsic origin. Laennec, looking on tubercle as vascularized, presumed the change to be intrinsic, and dependent on some morbid condition of vascular action; an hypothesis which existing knowledge refuses utterly to justify. Other pathologists taught that all changes in the consistence of tubercle depended on actions going on in the surrounding textures — suppurating, infiltrating, disintegrating. The latter doctrine is doubtless correct in part; a tubercle, softened at the periphery or even in its central parts, when these are permeated by natural textures, has in many instances simply undergone disintegration from saturation with fluids produced by those textures. But when a large mass of tubercle (as in the brain or in a lymphatic gland) liquefies in the centre, where it is absolutely beyond the reach of influence from the circumjacent tissues, some intrinsic change has evidently occurred. And this intrinsic change seems assimilable to that effecting softening of fibrinous clots in the veins, and is in intimate nature probably chemical.

Tubercle, once deposited, is not necessarily a fixture in the locality it occupies; on the contrary, its *removal* from the body is frequent, and occurs under different conditions and in different manners. It is effected; (*a*) probably by simple absorption; (*b*) by absorption combined with so-called "transformation;" (*c*) by elimination.

(*a*) Existing knowledge concerning the *simple absorption* of tubercle is far from satis-

factory. Our own belief (which is firm) in its occurrence rests upon the following facts and arguments. 1. Rabbits submitted to influences which, experience has proved, unfailingly lead to the development of tubercle in the liver and elsewhere, have subsequently been placed in conditions favourable to health, eventually been killed, and no traces, or the merest traces, of tubercle been discovered in their bodies. (Jenner, Baron, Carswell.) 2. Miliary tubercles, developed in the substance of pleural or peritoneal false membrane, disappear in cases where the latter becomes cellulo-serous in texture. 3. Tuberculous matter disappears from the substance of enlarged strumous glands. 4. We have seen and satisfactorily observed cases of tuberculization of the bronchial glands in children, in which (while the local and general symptoms of phthisis were fully developed, and the physical signs of marked enlargement of the bronchial glands were no less distinct) recovery in respect of symptoms has occurred, coevally with modification and ultimately disappearance of those physical signs. Such cases are unfortunately rare. 5. And, again, we have found the physical signs of induration at the apex of a lung in persons labouring under the local and general symptoms of phthisis, and belonging to a tainted family; and these signs have totally disappeared in company with the train of local and general symptoms. The event is, no doubt, singularly rare; and the disappearance of induration-signs may, by the sceptical, be referred to the cessation of congestion. But congestion has its special signs, which were not present in the cases we refer to; and congestion at the apex is, in the very great majority of cases, of tuberculous origin. 6. Andral and Reynaud attempt to trace certain furrowed and excavated appearances of pulmonary tubercles to a process of absorption, — but they do this dubitatively, and the point has not been investigated by others.

(*b.*) Of the removal by absorption of the animal ingredients of tubercle, while saline particles are deposited in abundance (so-called "transformation"), no doubt can be entertained. The gradual change of the tuberculous matter may be traced from a condition of mere desiccation with greasiness to the feel, to that of osteo-petrous substance. The traces of animal material may eventually almost wholly, if not wholly, disappear; for Thénard found that while "crude" tubercle contained 98.15 per cent. of animal and 1.85 of saline matters, cretaceous tubercle furnished but 3.0 per cent. of the former and 96.0 of the latter.

The production of this change in tuberculous matter is very frequently (but certainly not always — witness the case of the mesenteric glands) connected with the presence of common plastic exudation in the surrounding natural texture. This exudation-matter gradually hardens, eventually assuming the fibrous condition, and possessed (like all similar exudation) of strong contractile properties, probably facilitates the absorption of the enclosed tubercle by the pressure it exercises.

But absorption may proceed further. The cretaceous, calcareous, or osteo-petrous substances, representatives of bygone tubercle, sometimes totally disappear; and, at a later period still, the plastic fibrinous substance is itself removed. The part where all these changes have occurred (in the lungs for example) may even *appear* healthy; but on close examination puckering (parenchymatous, we mean, not pleural) is discovered in a spot, where obliterated vessels and bronchial tubes converge, as the indelible evidence of the morbid conditions that have preceded. This puckering and obliteration have (as we believe erroneously) been ascribed to the cicatrization of cavities.

(*c.*) The elimination of tuberculous matter by excretion is effected from free surfaces, or from the stroma of parts and organs.

1. Excretion of tuberculous matter, without breach of surface in the part supplying it, occurs in the uterine, renal, and pulmonary passages, — never, so far as we have ourselves observed, in the intestines. The occurrence is, under all circumstances, rare.

2. The elimination of tubercle from the stroma of parts involves the destruction of tissue by an ulcerative or gangrenous process. Such elimination takes place either when the cretaceous change has occurred, or independently of any such change. Of the former (the rarer of the two) the escape of cretaceous masses from the bronchial glands through an ulcerated opening in the trachea, furnishes a striking example; the expectoration of such masses from the lungs themselves is extremely rare, while, on the other hand, these organs supply the most important illustration of elimination of unchanged tuberculous substance.

Softening of tuberculous matter being complete, the natural textures contained within the area occupied by that matter have likewise lost their consistence, as a result of infiltration with morbid fluids and of imperfect nutrition. Ulcerative destruction readily sets in; minute bronchial tubes are in consequence opened; through these the softened matter and (as is proved by microscopical examination) fragments of the parenchymatous fibrils and capillaries of the lung are evacuated. An excavation (cavity or cavern) in the pulmonary substance is the result.

When a cavity is of recent date, its walls, smooth and even, are commonly lined, more or less completely, with plastic exudation, fragile, whitish, and opaque; but the pulmonary tissue is in some instances bare and unprotected. The walls of cavities of old date, firm and resisting, are lined with a membrane, divisible into two strata—the external dense, greyish, and fibrous, the internal soft and velvety, deposited continuously or in patches on the inner surface of the former. Or (as existed in one-fourth of the old cavities examined by Louis) the walls may be totally free from any membranous investment. The walls are uneven, irregular, and coated commonly by bands composed of pulmonary substance (rarely containing permeable vessels) studded with tuberculous

matter. Such cavities generally communicate with others, and always with bronchial tubes.

Cavities vary in size from that of a nut to very nearly that of the lung itself; the edges of the lobes being rendered continuous by pleural false membrane, and the pulmonary texture destroyed from base to apex. They form first at the apex, and more readily at its posterior than at its anterior aspect, and very rarely advance *pari passu* in both lungs. When of recent origin they contain pus and softened tubercle, with or without fœtor, in the different conditions already described. When of old date, on the contrary, they contain a dirty, thin, greenish fluid, with grumous particles suspended in it, and stained, or (as is most common) not stained, with blood. In rare instances fibrinous coagula, firm and adherent *, which may even be the seat of vascularization †, are found within them; and still more rarely portions of pulmonary substance, either gangrenous ‡ or free from such change. Vegetable productions of low type are often to be found amid the contents or upon the walls of cavities of a certain age.

The *course* and *event* of cavities are points of extreme interest.

1. Their most common course by far is to increase in size, through communications formed with softening tubercle on their confines.

2. They become stationary, the tuberculizing process having ceased in their neighbourhood. The double membrane lining them acquires more and more perfectly the characters and properties of the structures forming the inner wall of fistulæ; and they cease to exercise deleterious influence of any serious kind. The cure of phthisis is sometimes, according to Laennec, accomplished in this manner; but it is obviously necessary for the cure of the *disease*, not only that the cavity should itself become innocuous in the manner described, but that tuberculization should cease in the rest of the lung — that the rest of the lung should be healthy. Now we regret to be forced to state that during a search of several years carried on under peculiarly favourable circumstances, we *have failed to discover a single example of this fortunate coincidence;* nor do we believe (while to deny its *possibility* would be rash) that evidence has ever yet been furnished of its *actual occurrence*.§

3. That tuberculous cavities are capable of cicatrizing, and that they actually do cicatrize with very considerable frequency, was taught by Laennec, and has since his time been almost universally accepted as matter of established doctrine. We must nevertheless affirm that we have ourselves in *vain sought for a single specimen of cicatrized tuberculous cavity;* nor can we avoid deliberately questioning the fact of such cicatrization ever occurring.

The shape of fistulous cavities, the smoothness and polish of their internal surface, the fact that atmospheric pressure must act constantly on that surface, and, in fine, their structural analogy to fistulæ in other parts of the body, form so many *à priori* arguments against the possibility of cicatrization. Laennec saw their force; but certain observed facts led him to disregard them, and admit the reality of *partial* and *complete* adhesion of the apposed walls of cavities. These facts are as follow.

(α.) In the latero-posterior part of the upper lobe of a particular lung appeared a deep depression, containing a material solid and resisting. From the centre of this depression a white opaque lamina, about half a line thick, and of cartilaginous consistence, extended inwards, divided into two parts, and then reunited, thus forming a small cavity, which was filled with a yellowish-white, opaque, friable substance, much drier than common tuberculous matter. Here was (according to the assumption) a *partially closed* pulmonary cavity; and, be it observed, Laennec never saw more than *one* such case.

(β.) In the upper part, especially, of the upper lobes, Laennec frequently saw bands or nodules composed of condensed cellular or "fibro-cartilaginous" tissue, with a depression on the superjacent pleural surface, of variable depth, puckered, firm, and uneven, and with adhesion of the pleura at the corresponding point; the converging bronchial tubes being somewhat dilated in the vicinity, and obliterated in the exact site, of those bands or nodules. Further, these bands or nodules were always situated at the depth of half a line, a line, or two lines at furthest, from the surface of the lung; and were or were not distinctly continuous with substances of similar nature on the surface of the pulmonary pleura. Here were the assumed evidences of *complete closure* of cavities, — the puckering and thickening on the pulmonary surface showed that cicatrization had occurred underneath, but did not (as Laennec was often erroneously said to have maintained) in any measure constitute the actual substance of cicatrices.

But it may be objected to this doctrine: — that the superficial puckering is often seen, where subjacent cellular bands or nodules cannot be discovered; — that it frequently

* Univ. Coll. Museum.

† Louis.

‡ Some time since a patient of ours expectorated a fetid mass, about the size of a large pea, presenting under the microscope, and even to the naked eye, the characters of pulmonary tissue. This is the only instance of the kind that has ever occurred to us.

§ M. Louis relates a case (Op. cit. Transl. p. 19, case 3) in which a solitary excavation lined with pseudo-membrane of *recent* origin, existed at the apex of one lung in the midst of healthy tissue; and considers it presumable that, if the patient had survived a short while longer, the membrane in question would have assumed the fistulous characters we have above described: under these circumstances a cure of phthisis would have been accomplished. But in the first place it was not accomplished; in the second it appears extremely doubtful (for reasons which M. Louis has anticipated, but not, as we think, satisfactorily set aside) that the excavation was of tuberculous rather than of purulent origin; and in the third the eventual assumption of the fistulous characters, in this particular case, is matter of hypothesis.

exists at the base of the lung, where cavities are excessively rare ; — that such puckering is so common that, if it really signify closure of cavities, this must be admitted to be an every-day occurrence—an admission to which the laws of general pathology and special clinical experience are equally opposed ; — that the alleged cicatrices are always (as insisted upon by Laennec himself) either actually under, or only a line or two distant from, the pulmonary surface, whereas cavities are frequently seated deeply in the lung ; — that Laennec's clinical evidence in support of closure of cavities is exceedingly defective, and that were cicatrization so common, as on his principles it must be, the opportunity of *tracing the progress of contraction during life* would frequently occur, whereas it has certainly never yet occurred to ourselves, nor (so far as we are aware) *as matter capable of demonstration* to any one else.

Laennec's anatomical facts were correctly observed, but he misinterpreted them pathologically. The cellulo-fibrous bands or nodules he noticed appear, in truth, to be formed in either of the three following ways. (1.) They are primary productions, generated quite independently of tuberculization ; — results of *local* inflammation perfectly assimilable to the bands permeating more or less completely the entire substance of the lung, in certain cases of *general* chronic sub-inflammation of the organ. (2.) They are produced in the manner already explained (p. 108), in connection with tubercle undergoing absorption. (3.) They are altogether *extra-pulmonary* productions, and their apparent position *within* the parenchyma of the lung, a fallacy more or less easily exposed.

Under all these circumstances their alleged direct relationship to cavities is matter of pure imagination ; but the last mentioned condition of things only (which has been insisted on principally by M. Fournet), needs to be dwelt upon here.

As a preliminary point, let it be observed that viscera invested with serous membrane are liable to undergo indentation by the contraction, and in the site, of plastic exudation. Even the liver, dense as it is, we have occasionally seen pretty deeply indentated in this manner ; more frequently is this observed in the spleen, but still more so (obviously from the yielding character of its texture) in the lung. Now, in the particular cases we have in view, the following points may be traced. 1. Pleurisy occurs, local or general, with or without liquid effusion. 2. The resulting plastic exudation penetrates or not into sulci on the pulmonary surface formed by creasing ; these sulci are deeper if liquid effusion has occurred, than under the contrary circumstances. 3. The plastic exudation is thicker at some points than others, and there excess of depression takes place, because its own contractile force, and the force resisting atmospheric (excentric) pressure, are both greatest there. 4. Processes from this superficial exudation penetrate into the sulci (we have seen them three quarters of an inch long). 5. The thinner *peripheral* portion of the plastic exudation on the pulmonary surface becomes by-and-by cellular in texture, eventually undergoes more or less complete absorption, and the immediately subjacent portions of lung rise up on the removal of the pressure ; the *central* and thick part of the exudation (itself become meanwhile more or less distinctly fibrous in texture) appears deeper than ever in the lung, while the perfect adhesion of the edges of the sulcus in which it lies, renders the illusion complete as to its being seated in the actual substance of the lung. 6. The adjoining pulmonary tissue may be simply condensed, or may be solidified with infiltrated plastic exudation; in either case (but especially the latter) obliteration of the minute vessels and bronchi takes place. The pulmonary tissue, yet beyond this, may become emphysematous.

The more frequent occurrence of these appearances at the apex than elsewhere, is the obvious consequence of the great proportional frequency of *local* pleurisy there, — itself dependent on the frequency of irritation set up by tubercles in the neighbourhood. The condition of the minute bronchi in the implicated parts, is of itself a strong argument in favour of the doctrine we have set forth ; those tubes are contracted and obliterated as they would be from pressure and disuse, they are not abruptly cut across, as they would be were Laennec's cicatrization-theory in accordance with facts. According to M. Fournet, the deep sunken, fibrous nodule may become the interstitial seat of puriform or of calcareous deposition. In this way he explains Laennec's solitary example of *partially closed* cavity, already referred to. We have not seen this condition ourselves : the thing is no doubt possible, but it must be very rare. In taking leave of this question we would observe, that the nature of this work has prevented us from giving it the full development it really merits, but we trust enough has been said to make the main fact intelligible. That fact is doubtless disheartening to the therapeutist ; and we should regret any active part we may have taken in establishing it, did we not look forward on some other occasion to proving, that anatomical cure *by absorption*, in the manners already described, is of more common occurrence than is generally supposed.

Many of the influences, irritative and mechanical, exercised by tubercle on surrounding textures, have been spoken of in the foregoing pages ; the generation of new vessels attending the progress of tuberculization in the lung, will be touched upon in the section on NEW VESSELS in another part of this article.

§ 3. PURULENT DEPOSIT, OR PUS.

PUS is a fluid of whitish-yellow or greenish colour, and homogeneous aspect ; of faint, peculiar smell, when warm ; inodorous, when cold ; of creamy consistence ; and of sweetish, or sometimes saltish, taste.

Pus consists of a liquid part (*liquor puris*) holding in solution organic principles and inorganic salts; and of a solid part (*corpuscles*) held in suspension in the liquor puris. These constituents separate spontaneously, after removal from the body, with a degree of slowness increasing as the purity of the pus; when the liquor puris is in excess, the corpuscles sink rapidly. The corpuscles are not separable from the liquor puris by filtration. Pus does not naturally contain gas of any kind (J. Davy). Its specific gravity ranges between 1042 and 1021, the weight most commonly observed being about 1030.

Four kinds of organic corpuscles are found in pus: (1.) Proper pus-corpuscles; (2.) Pyoid corpuscles; (3.) Granules; (4.) Compound granule-corpuscles.

(1.) The proper pus-corpuscle is a body of tolerably spherical outline, unless when accidentally flattened or otherwise altered in shape by the pressure of adjoining corpuscles; its edge, slightly dentated, as we have commonly seen it, may be perfectly even; its surface finely granular-looking. The corpuscle is (commonly, but not always,) moderately transparent, subjacent bodies being visible through it, as is particularly obvious when a weak iodine-solution has been added to the fluid. The diameter of the corpuscle varies from the $\frac{1}{1800}$ to the $\frac{1}{2300}$ of an inch,—averaging about the $\frac{1}{2000}$. Its substance is somewhat elastic. It never, as far as we have seen, presents a narrow edge to the eye, in the manner of the red corpuscle of the blood.

The contents of the corpuscle are semi-fluid and solid. The semi-fluid substance seems of slightly gluey consistence. The solid contents are the nucleus or nuclei. It was long taught that if the pus examined be recent, and chemically unchanged, the nucleus is not perceptible even with strong magnifying powers. This is now known to be erroneous; we have, with a glass magnifying only 400 diameters, detected a nucleus in laudable pus of neutral reaction, immediately after removal from the body.* But, under the influence of dilute acetic acid, the nucleus is more fully brought into view, and is seen close to the cell-wall, in the form of a bipartite, tripartite, or quadripartite body (more rarely a single one), all the divisions of which lie nearly on the same plane side by side. Each division of the nucleus is smooth, circular, or slightly oval, and biconcave. The central depression, which exists as a consequence of its biconcave form, either appears opaque, while the surrounding part is clear and transparent, or the former is transparent and the latter opaque,—differences depending on variation of the focus of the microscope. The surface of the nucleus is very finely granular; its diameter varies from the $\frac{1}{6500}$ to the $\frac{1}{6000}$ of an inch.

* The facility of its discovery depends upon the transparence and thinness of the cell-wall; and the amount of these, upon the youth of the corpuscle. In our work on Cancer (*fig.* 6) are figured nuclei visible without the aid of acetic acid.

(2.) Under the name of *pyoid*, M. Lebert* distinguishes a corpuscle smaller than that just described; spherical in shape, tolerably transparent, rather of solid than liquid consistence; containing from four to ten granules or more in their interior, and wholly unprovided with nucleus, acetic acid simply rendering the corpuscle more transparent. These bodies, resembling most closely the cells of tubercle (p. 105), are larger and more spherical than these: so great is the similarity, that M. Lebert was at first led to consider the pyoid corpuscle peculiar to tuberculous pus; but, subsequently finding it (as we have also done ourselves) under circumstances excluding the idea of tubercle, has relinquished this notion.

(3.) The *elementary granule* seen in pus is of spherical shape; it is never cupulated, so far as we have seen, and is less than half the size of the nucleus of the pus-corpuscle, averaging the $\frac{1}{14500}$ of an inch in diameter. These granules are obviously not, as was once maintained, detached nuclei floating in the liquor puris. They are either single and solitary, or (less frequently) collected in irregular groups. Their composition varies, as they are sometimes soluble in æther, and sometimes exhibit the reactions of a protein-compound; this chemical difference is not always connected with any physical peculiarity, which the eye at least can detect.

(4.) The *compound granule-corpuscle* (compound inflammation-globule; Gluge) does not occur in large numbers in pus; many drops may be examined without a single one presenting itself. This corpuscle is of spherical, and slightly irregular, form, ranging from $\frac{1}{1330}$ to $\frac{1}{1100}$ of an inch in diameter (*fig.* 92); and composed essentially of granules and an involucrum. The involucrum is not dissolved by water, and simply rendered transparent by acetic acid; the granules vary from ten, to twenty or thirty, or even many more in number. Occasionally the action of acetic acid discloses a single, double, or multiple nucleus lying close to the involucrum. The granules are likewise kept in situ by a fluid of thickish consistence, in which, if few in number, they may be seen to move. The course of formation of these corpuscles seems to be,—agglomeration of granules from exudation matter, investment with a membranous wall, production of a nucleus.

Fig. 92.

Compound granule-corpuscles (magnified 400 diams.).

a, in the natural state, diam. $= \frac{1}{1330}$ to $\frac{1}{1100}$ of an inch; *b*, corpuscle about to undergo rupture, the involucrum being more transparent, and the granules larger, darker, and more prominent; *c*, a corpuscle treated with dilute acetic acid, the involucrum being rendered transparent, and several nuclei appearing in its interior.

* Physiol. Patholog. t. i. p. 46. 1845.

Fat occurs invariably in more or less quantity in pus, and exhibits itself under the microscope, under the forms of molecular granules, as above referred to; oil globules; crystals of cholesterin.

Saline crystals occasionally occur in pus, especially in certain unhealthy varieties of the fluid. When they exist, some peculiar circumstances have probably caused unusually rapid, or otherwise modified, evaporation of the liquor puris.

Infusoria (monads and vibrions, especially the vibrio lineola) occur in pus: we are unable to affirm whether their presence is always an evidence of decomposition in the pus itself. The attempt, made by Gruithuisen, to distinguish various fluids by the characters of the infusoria developed within them, has not led to any satisfactory results.

Pus, when recent and healthy, has a slightly alkaline reaction; we have known it neutral, however, in cases where there was no reason to believe any chemical change had occurred. It readily becomes acid from the development of an acid — the lactic it is supposed: the change from one to the other reaction, evidently depends, in some cases, on a primary change in the constitution of the pus at the moment of generation; for we have found pus from the same wound, sometimes alkaline, sometimes acid, though taking all precautions to ensure its examination at the moment of production.

The published analyses of pus are extremely numerous. Among the most recent and carefully conducted are several by Dr. Wright *, of which the following may be selected as specimens; it is clear that the chemical constitution of the fluid must vary somewhat with the locality from which it has been derived, inasmuch as pus can very rarely be obtained free from minute quantities of the textures or secretions in connection with which its production has occurred.

	Pus from a Vomica.	Pus from a Psoas Abscess.	Pus from a Mammary Abscess.
Water	894.4	885.2	879.4
Fatty Matter	17.5 }	28.8	26.5
Cholesterin	5.4 }		
Mucus	11.2	6.1	
Albumen	68.5	63.7	83.6
Lactates, carbonates, sulphates, and phosphates of soda, potash, and lime	9.7	13.5	8.9
Iron	A trace.		
Loss	3.3	2.7	1.6

Some of the discrepancies in the results given by various experimentalists, doubtless depend in no small degree on the differences in the manner of conducting their analyses. Making allowance for these sources of error, it may be inferred that liquor puris consists of water varying in proportion from 76 (Von Bibra), and 82 (Dumas), to 90 (Lassaigne, Pearson, and Von Bibra *) per 100, of dissolved albumen, of fibrin, fat, and extractive matters. A peculiar principle (precipitable by acetic acid and by alum) has been assigned to pus, under the name of *pyin*, by Güterbock: that such a special substance exists independently of the means employed to procure it, has been questioned or denied by Valentin, Dr. John Davy †, and others. At the present hour the real presence in pus of the principle, described under this name, is admitted by chemists; it is said (probably *pro tempore*) to be tritoxide of protein. Glutin is enumerated by Martins ‡ among the constituents of the pus of empyema; its existence must be an exceptional occurrence. Phosphoric, hydrochloric, and lactic acids in union with lime, potassa, soda, magnesia, and ammonia, form the ordinary saline elements of the fluid. Oxide of iron, though put forward as a constant ingredient by Cruickshank, Koch, Krauss, Göbel (in the horse), Pearson, and Güterbock, is in all probability only present in instances of accidental admixture of blood.

The micro-chemical properties of the pus-corpuscle are important. Pure water exercises no obvious influence on it for days, even, except that of rendering the nucleus more visible, and slightly increasing its size by passing through the cell-wall by imbibition. Saturated sugar-water, blood, mucus, and saliva, unless (as observed by Henle) the latter be acid, produce scarcely any alteration in the corpuscle. Urine gives it an extremely ragged outline in the course of a few days (earlier if it be alkaline), and eventually breaks it up completely. Alcohol slightly corrugates, without dissolving it. Under the action of acetic acid the corpuscle loses its granular appearance, commonly undergoes a change of bulk; and the distinct outline of the involucrum fades away, while the nucleus, simple or compound, becomes clear and distinct. What is the nature of these changes? The removal of the granular aspect of the corpuscle is not readily explained. We were at one time disposed to regard it as produced by the simple unfolding of the involucrum, caused in turn by imbibition of the fluid re-agent, — believing that the granular appearance arose simply from a corrugated state of the surface of the involucrum. But the uniformity of the granular appearance, its constancy of occurrence, its extreme delicacy, and the fact that it is not removed altogether, no matter how distinctly the corpuscle be swollen by imbibition, appear to throw doubt upon this view, and render it more probable, if not actually certain, that it depends on the presence of molecular matter within the involucrum; — the change of bulk is sometimes one of increase, sometimes one of decrease, — a difference which has appeared to us traceable to the

* Medical Times, January, 1845.

* Untersuch. über einige verschiedene Eiterarten. Berlin, 1842.

† Physiological and Pathological Researches.

‡ Annalen der Pharmacie.

varying degrees of dilution of the acid. That the involucrum fades simply, without being, as was at one time supposed, destroyed, is commonly obvious on simple inspection; it appears as a sort of thin, transparent halo round the nuclei. But, were there any doubt, this would be removed by the addition of solution of iodine *, which restores the clear definition of the cell-wall. The fading of the involucrum is, however, an early stage of solution; for, if much acid be added, the halo disappears and cannot be restored. In respect of this disclosure of the nucleus three opinions have found their supporters: (*a.*) that a simple or compound nucleus, pre-existing in either form, is simply rendered visible by the acid; (*b.*) that it is exposed and, besides, split up into parts; (*c.*) that it is an appearance altogether produced by the acid. That the first of these opinions is the correct one, appears (if on no other grounds) from what has been said in a previous page on the discovery of the nucleus in recent unchanged pus.

Mineral acids, if dilute, do not dissolve the corpuscles; if concentrated, dissolve them completely. Caustic alkalies form a jelly with them; their carbonates, as also muriate of ammonia, change them similarly but more slowly. The action of the latter on pus was observed by J. Hunter on a large scale, and ascribed by him to coagulation of the liquor puris. Dr. J. Davy showed, by allowing the corpuscles to settle, decanting the supernatant fluid, pouring some of the muriate upon this, and observing that no viscidity followed, until corpuscles had been added, that the change depended upon these. Dr. Wood † ascertained that the muriate causes the corpuscles to adhere with some closeness to each other.

Pus-corpuscles contain a very little phosphate of lime, and consist essentially of a protein-compound. Their constituent substance has been given the special title *purium* by Koch, *purulina* by Michelotti; a mode of naming it which must be abandoned if, as Lehmann and Messerschmitt maintain, the nucleus and involucrum belong to two different varieties of protein, — the former being composed of venous, the latter of arterial, fibrin.‡ But this view is, it is scarcely necessary to add, itself far from being established, — as also that of persons who (imitating Ascherson) hold the centre of the nucleus to be composed of fat, and its peripheral part of albumen.

Pus differs chemically from blood in the states of health and of hyperinosis in the proportion of its ingredients, much more than in their nature — as might readily be imagined. But quantitative analyses are as yet so imperfect, that very different general inferences may be deduced from them according to the selection made of published analyses; — it is true this may also in part depend on the actual variation in the proportions in different specimens of pus. Thus we may prove by one set of experiments that pus contains more water than healthy, and *à fortiori* than hyperinotic, blood; and, by another, that pus is on the contrary a more concentrated fluid than either. And whichever be the opinion adopted, theoretical explanation and support may readily be found for it. The following general inferences are likewise, we confess, to be accepted with caution.

Pus contains more albumino-fibrous substance than the liquor sanguinis of either species of blood, less than the blood in mass, comprising the red corpuscles. The latter point obviously depends on the fact that the corpuscles are, as such (unless accidentally and in very minute proportion), retained within the vessels; whereas pus is formed outside them. But how comes it that pus contains proportionally more albumino-fibrous material than the liquid part of the blood — that part of the blood which is exuded in inflammation, and which forms the substance for the evolution of the purulent matter? The peculiarity (as suggested by Lebert) is probably due to partial solution of the red-corpuscles in the liquor sanguinis, and transudation of that dissolved substance; an explanation not, we may observe, without apparent connection with the established fact of the decrease of red corpuscles in hyperinotic blood. To this source (as well as to extravasation) may, perhaps, be referred the occasional appearance of a little iron among the elements of pus.

Fat is much more abundant in pus than in blood; the high ratio of cholesterin in the former (as ascertained by Valentin *, Von Bibra and Wright) comes in confirmation of the fact established by Becquerel and Rodier†, that the ratio of cholesterin in the blood is always increased in inflammation. The saline constituents of the two fluids do not differ very materially.

Pus possesses a remarkable power of resisting decomposition; at the end of months some corpuscles may still be found unchanged, among others that are dissolved. It even retards the putrefaction of substances with which it is brought in contact, as shown by the experiments of J. Hunter and Everard Home. The latter observed that pieces of flesh placed in fresh pus underwent gradual diminution of weight, and eventually solution, without any evidence of putrefaction being manifested. Ultimately, pus does putrefy however; the occurrence of the change being much hastened by the presence of blood, mucus, or other organic fluids. Acidity, as already hinted, is one of the earliest signs of the change.

* The corpuscles, and especially the nuclei, attract the iodine from the fluid in which they swim; for, while they darken, this fluid loses its yellow-brown colour.

† De puris natura atque formatione. (Berol.)

‡ Medicin. Vierteljarhschrift von Roser and Wunderlich, 1842, S. 247. The same writers regard the molecular granules of pus as composed of yet another variety of protein-compound, resembling Keratin.

* In one of Valentin's Analyses (Repertorium S. 307, 1838) the proportion of cholesterin is so high as 11.86 per 1000.

† Gazette Médicale de Paris, 1844.

The various appearances of pus have given rise to its classification into the creamy, curdy, serous, and slimy varieties (Pearson); one obviously unfit to represent the existing state of knowledge. It seems better to consider pus as of two kinds: I. Simple; II. With added characters,—the added character being derived either from (A) Substances of known nature, natural or morbid; or from (B) Substances of unknown nature, called viruses.

The pus-corpuscle has uniformly the same character in all descriptions of pus. The distinction of the varieties above enumerated, therefore, can only be microscopically effected (if it can be effected at all) by means of superadded elements; and most valuable these are as diagnostic of its seat and production in many instances.

The varieties of pus comprehended in the class (B), differ from those in the class (A), in being *inoculable*, — a character dependent not upon any peculiarity of their cell, but upon the associated intangible "virus." Some of the varieties of the class A possess, however, what may be called *pseudo-inoculability*, namely, those in which certain parasites are present. The pus of scabies is thus to be propagated by means of its entozoon; that of porrigo by its entophyte; but it is clear that the associated pus has in reality nothing to do with the transmissibility of the diseases.*

There are three semi-fluid matters, which it is important to distinguish from pus, namely, *mucus*, *softened fibrin*, and *fluid holding epithelium in suspension*. The distinctive characters most to be relied on are as follow: (*a*) *Mucus*. (1.) Pus mixes with water, being at first equally diffused through it, so as to give it a yellowish tinge; subsequently, the corpuscles fall to the bottom, and leave the supernatant fluid clear and colourless. Mucus does not mix with water, but eventually renders it slimy. (2.) Pus forms an emulsion with acetic acid, from which, after a time, the nuclei of the corpuscles are thrown down as a yellow sediment, while the involucra are dissolved. Mucus is coagulated by acetic acid, and forms a membranous flocculent mass without mixing with the acid; at the same time it becomes less slimy and more consistent. (3.) Pus forms a ropy mass with the caustic alkalies, or with their carbonates. (B. Babington.) Mucus, on the contrary, is rendered thinner, and partially dissolved by them. (4.) Pus contains fat removeable by ether, sometimes in such quantities as to render it inflammable; mucus contains none. (5.) Air bubbles in pus collapse the moment they are formed; in mucus they remain for a time—for days even—unaltered. (6.) Equal parts of concentrated sulphuric acid and pus form a dull brown-red solution, becoming paler and turbid by the addition of water; mucus, on the contrary, forms a pale brown fluid with this acid, which remains clear and becomes colourless on the addition of water. (Brett and Bird.) (7.) According to Preuss, pus (as also tubercle) is distinguishable from mucus by containing iron (which may be shown by inceration and digrating the ash in gum, hydrochloric acid, diluted with five parts of distilled water, and then adding a few drops of ferro-cyanide of potassium): but in point of fact the presence of iron is due to accidental admixture with blood. (8.) Pus pressed between two plates of glass and held before a candle, presents an iridescent appearance; no such effect is observed with mucus. (Young.) The state of knowledge concerning the two alleged principles, mucin and pyin, is too unsettled to allow of just inferences being drawn from the presence or absence of either.

Various attempts have been made to distinguish pus and mucus by means of the proper corpuscle of each. The difficulty experienced in the detection of distinctive characters gradually led to the suspicion that the corpuscle of both fluids might be one and the same thing; and the inquiries of several competent persons appear at length to have distinctly established the fact, that healthy mucus contains no special corpuscle, but that, under the very slighest irritation of a mucous surface, pus, with its special cell, is thrown out, which cell had been mistaken for one peculiar to the natural secretion of mucous membranes. The presence of a bougie in the urethra for a very short time suffices to cause the production of *muco-pus*.* The abundance of epithelium-scales in mucus is sometimes a useful aid in the diagnosis: the nuclei of these scales set free may, doubtless, also have been sometimes mistaken for special corpuscles.

(*b*.) *Softened Fibrin*. — The semi-liquid matter frequently found in the centre of coagula in the veins and heart, was long confounded (from its colour, consistence, and easy miscibility with water,) with pus; notoriously so by MM. Gendrin, Andral, Cruveilhier, and Magendie. It had been more or less confidently affirmed, however, by MM. Dupuytren, Burrows, Davy, and others, that this matter really consisted of softened fibrin, and not pus, when Mr. Gulliver† gave support to this notion by pointing out the following peculiarities, distinguishing the substance in question from pus: 1. It is not rendered ropy by caustic volatile alkali. 2. It presents no iridescence when pressed between plates of glass before a candle. 3. Under the micro-

* Donné describes an animalcule, under the name of Tricomonas vaginalis, as peculiar to the female syphilitic discharge, and constituting the infection-agent. But it is not found in the male, and is often absent in the female; its powers in the latter quality may be more than doubted. Froriep (Notizen, 1837, No. 25. p. 40.) thinks the animalcule, peculiarly connected with the female genitals, but not specially with syphilis; and regards it with Ehrenberg (Notizen, 1837, No. 28. p. 88) as a species of acarus. This matter requires revision; it has even been suggested that Donné and his followers have mistaken ciliated epithelium-scales (to which indeed the figure of the former bears much resemblance) for animalcules.

* That is as far as the generation of pus-corpuscles is concerned; the production of liquor puris is a more elaborate process.

† Med. Chir. Trans. vol. xxii.

scope it is mainly composed of a finely granular mass, and often contains large, irregular, flabby particles, with globules of various sizes. But these globules bear but a very small proportion in number to those in pus; and, on the addition of acetic acid, they soon disappear, except a few which seem more compact, and require a longer time for solution: they are probably altered blood-corpuscles. 4. Softened fibrin more readily becomes putrid than pus. Fibrin removed from the body and subjected to a blood-heat, begins to change into matter, such as that now described, in forty hours.

We have had numerous opportunities of satisfying ourselves of the general accuracy of these observations of Mr. Gulliver; but we cannot accede to the notion that the yellowish-green, soft, sometimes almost diffluent coagula, frequently seen in veins (coagula which, according to the spirit, if not the absolute letter, of Mr. Gulliver's doctrine, should consist merely of softened fibrin and accidentally-imprisoned blood disks), never contain, and hence never consist, in part, of pus. We have more than once discovered fully-formed and well-conditioned pus-corpuscles in such coagula, which, upon mere naked-eye evidence, we had regarded as wholly composed of softened fibrin. We refer here to cases where no signs of inflammatory (or other) alteration exist in the coats of the vein, and where those coats appear to have nothing to do with the appearances referred to; for the corpuscles appear chiefly, or it may be altogether, in the centre of the coagula. Now such cases seem to prove one or other of the following three propositions: That corpuscles exist, having all the micro-chemical characters of those of pus, yet in reality of a different nature; that stagnating liquor sanguinis is capable of undergoing, in its own proper substance, inflammatory changes; or that the pus-corpuscle is capable of forming, in stagnating liquor sanguinis through some peculiar influence of non-inflammatory nature. Reason, collateral experience, and the general laws of pathology, point to the second of these propositions as the most probable of the three; but it is wisest for the present, perhaps, to refrain from adopting any one of them.

(*c*.) *Epithelial fluid.* — Broken or perfect epithelial scales sometimes accumulate in very considerable quantities in certain serous fluids; and the resulting mixture cannot with the naked eye be positively distinguished, either by colour, consistence, or odour, from pus. In the Fallopian tube (somewhat dilated) of an anasarcous woman, who died under our care at University College Hospital some time since, we found fluid of this kind, containing (as shown by the microscope, the only test in such cases,) not a single pus-corpuscle, but abundance of epithelium. We have seen the same kind of fluid in the pelvis of the kidney.

The microscopical distinctions of the unaltered red-corpuscle of the blood, and the pus-corpuscle, are so numerous and obvious that they need not be enumerated; it is impossible to confound the two objects. The red blood-corpuscles, however, when acted upon by various re-agents (serum, urine, pus, artificially added saline solutions, &c.) acquire a more or less accurate resemblance to those of pus; they in truth increase somewhat in bulk, lose their regularity of outline, which becomes ragged, and alternately notched and studded with minute prominences, — appearances which have led to very remarkable errors. Nevertheless, the resemblance is far, even, from seemingly perfect; the altered red-corpuscle is smaller than the other, and is not minutely granular on the surface: if there be doubt, however, in the case, acetic acid, by dissolving the body (if it be a red-corpuscle), or producing the changes already described (if it be one of pus), will settle the question.

The colourless corpuscle of the blood in its unaltered state is with difficulty distinguishable from the pus-corpuscle; the two bodies have, by practised observers even, been confounded. It has the same minutely granulated aspect; and acetic acid discloses, as in the pus-corpuscle, a nucleus in its interior. The colourless corpuscle is smaller than the other, however (the mean ratio of their sizes being as 22 to 27, nearly). The nucleus is either single, bipartite, or tripartite.

The process by which pus is formed — in other words, pyogenesis or suppuration — was long supposed to be one of disintegration and solution of the natural tissues. We need not devote space to the elaborate refutation of this rude conception: suffice it to say, that pus may be produced for years from mucous membranes, without even abrasion of their surfaces having occurred, and that the elementary textures (e. g. the cellular) may, at the outset of the suppurative process, be shown to have retained all their natural properties.

We might, on the score of its obvious fallacy, similarly pass by the notion that the corpuscles of pus are simple modifications of the red-corpuscles of the blood; but as, even recently, symptoms of a return to this previously-exploded idea have appeared on the Continent, a few words on the subject seem called for. M. Gendrin (*Hist. Anat. de l'Inflammation, &c.*) taught that in consequence of the stagnation of the red-corpuscles induced by inflammation, those bodies are first converted into pus-corpuscles in the interior of the capillary vessels, and, secondly, exude thence into the intercapillary texture. The experiment upon which the first portion of this doctrine was based has been repeated by Dr. Wood*, Mr. Gulliver, and others; and either no appearance at all of the alleged puriform matter discovered, or its characters proved to be those of softened fibrin. As respects the exudation of ready-formed pus-corpuscles, the theory manifestly involves an impossibility, as the structure of the walls of the capillary vessels is too close to permit the passage of bodies of such dimensions.

* Op. Cit. p. 4.

Besides, M. Gendrin has forgotten to explain why, if the pus-corpuscles escape from the vessels, the blood-corpuscles, of much smaller size, as they are, do not follow abundantly in their track. M. Donné* some time since revived the idea of conversion, believing that he had seen red-corpuscles changed into purulent in a mixture of pus and blood *out of the body:* he was deceived by the physico-chemical changes already referred to, which pus, like various other fluids, effects in the blood-corpuscles.

The true doctrine of pyogenesis is a modification of that of "secretion" taught by Simpson (1722), de Haen (1756), Morgan (1763), Brugmans (1785), and John Hunter. The direct microscopical evidence, upon which it has been finally established, was originally and mainly supplied by Wood, Gueterbock, and Henle. This evidence is to the effect that, as a general fact, the generation of the solid materials of pus takes place wholly outside the vessels in a hyaline blastema. In that blastema granules first appear; subsequently, bodies of larger size form, either independently of the granules or around them, and, collecting in variable numbers, or remaining single, present the characters of, and actually constitute, the nucleus of the pus-corpuscle. The involucrum, or cell-wall, next forms; and, at first clear and transparent, subsequently grows granular. One of the readiest plans of observing this series of changes, is by using the exudation-fluid from a blistered surface,—but the same phenomena may be traced on wounded surfaces.

The elementary tissues of the body are not at first altered in any appreciable manner by the occurrence of suppuration among them†; solution of their substance may at length be, and frequently is, more or less completely effected. This solution-process is of triple nature: it is *physical*, in that mere maceration aids in its production; *chemical*, in that in certain unhealthy states of the system, solvent agents, &c.‡ are generated in suppuration; *vital*, in that the tissues themselves, in certain constitutional conditions, lose partially or completely their force of cohesion.

§ 4. MELANIC DEPOSIT.

Black colouring matter appears under various conditions as a morbid deposit. The only kind strictly belonging to the present head, is true melanic granule or cell-pigment, more or less closely similar to natural pigment.

Melanic pigment is essentially composed of extremely minute granules, for the most part contained within cells. The cells are of various shapes, commonly rounded, however; not commonly of caudate form, but often showing a tendency to prolongation in one particular direction. They very rarely contain a nucleus.

* Arch. de Méd. Juin, 1836.

† The first change discoverable under the microscope seems to be loss of elasticity.

‡ Prussic acid, according to Dumas. (Comptes Rendus de l'Institut, 1841.)

The cells are of blackish, brownish, bistre or yellowish tint, the colour evidently depending on the granules. And these granules are not confined to the cells, but are commonly found, in multitudes, free; when excessively minute they are the subjects of molecular motion. In some instances cells are not to be discovered at all.

Little is positively known concerning the development of melanic pigment,—either of the mode, whether exogenous or endogenous, by which increase of cells takes place,—or of the relationship in which the cells and granules stand to each other; that is, whether the cells are formed around the granules, or the granules generated within the cells. But while it is certain that the cells are deficient in the attribute of permanency, and appear of secondary importance (seeing that the pigment character may exist in perfection independently of them through (the granules alone), it seems very unlikely that they are truly vegetative. Melanic cells never exhibit any tendency even to cohere—much less to form the basis of a stroma.

The chemical composition of this substance is not known with accuracy. Analyses in numbers no doubt have been printed, but none of them are entitled to confidence,—either because they include the composition of associated substances, organic and inorganic, or because the black matter analyzed was not really composed of cell-pigment. It is probable, however, that the ultimate constituents are the same, and associated in, at least very closely, the same proportions, as of the pigment of the choroid coat. Some of the more important reactions of this substance, as set down many years ago by Henry, may be substantiated readily, and have frequently been confirmed by ourselves. A "softened melanotic tumour" was experimented on: 1. By filtering through paper, much of the colouring matter remained on the paper, and the colour of that which passed through was rendered much less intense; 2. Boiling does not destroy the colour, not even when a little caustic potass has been added; 3. It is not changed by acids even when heated, except by strong nitric acid, which turns it yellow; 4. A stream of chlorine, passed through the liquid, destroys the colour, and throws down light-coloured flocculi*; 5. A few grains of corrosive sublimate (nitrate of mercury and muriate of tin also, though more slowly,) precipitate the colouring matter and leave the supernatant fluid clear.

Black cell-pigment occurs under two chief conditions—*unassociated*, or *associated* with other materials. The former condition is excessively rare, and we have certainly never seen it in the human subject,—that is, we have never seen a fluid or solid accumulation of cell-pigment utterly unmingled with other fluids or solids, natural or adventitious: it ap-

* Chlorine water (which we have used) does not actually *destroy* the colour, but diminishes its intensity greatly.

pears, however, to occur thus in the horse. In the associated form it is of very common occurrence, exhibiting itself in the form of points, spots, layers, or masses, in the substance of natural textures or of adventitious products. In the latter condition it has more particularly excited attention, and been described under the titles of "melanosis," "melanotic tumour," "melanoma," &c. A full consideration of the modes of connection of cell-pigment with tumours will be found under the head of "Melanoma" in the section "Growths."

The substance we have just described being the only true black *cell-pigment*, appears to be the only one legitimately falling under the present head; but it is absolutely necessary (were it only for the purposes of diagnosis) that we should briefly consider certain other causes (most ably investigated by Dr. Carswell) of black discolouration. These causes are, (*a.*) Alteration of the colouring matter of the blood; (*b.*) Introduction of black-coloured substances from without.

(*a.*) *Alteration of hæmatosine.*— *Stagnation and extravasation*, and the *action of certain chemical agents*, are followed by this alteration.

Stagnation produces its effect on the colour of the blood most distinctly in the capillary vessels, is more common in old than in young persons, and attends diseases of the heart and great vessels interfering with the circulation. Chronic inflammation is the most common immediate cause of the stagnation; the intestinal canal and the lung the most common seats of the altered colour. In the intestinal canal, it is difficult (except by ascertaining the absence or presence of acid) to separate the effects of chemical agency from those of mere stagnation.

Extravasated blood (occupying localities altogether removed from the influence of chemical action not originating in itself, as, for example, in the common cellular membrane,) sometimes undergoes remarkable change of colour, becoming of a pitch black hue. The blackish and slaty discolouration frequently seen in points or patches under the mucous coat of the pelvis of the kidney, and also on the surface of the cortical substance, is evidently produced by infiltrated and altered blood. In these cases no pigment-cells are to be discovered, an amorphous granular mass exhibits itself, not materially differing in physical characters (it is not, however, mixed with crystals and fragments of tissue,) from the colouring matter of gangrenous detritus.

Chemical action is a frequent cause of blackening of the blood. Blood poured into the stomach, and sometimes even if retained within its veins, is blackened by the gastric juice, either by direct contact or by imbibition. The effects of the acid secretion are precisely such as are producible by acids on blood removed from the body. The slaty discolouration of the anterior border of the liver, so common an appearance, is similarly explicable; the blood in its capillary texture being acted upon by hydro-sulphuric acid gas transuding through the adjacent intestines.

(*b.*) *Introduction of black coloured substances from without.* — The lung (with its appendages) is the only organ in which this source of discolouration has been established. Pearson* was the first to suggest, that inhaled carbonaceous matter was the true cause of the black lines and patches (following the course of the lymphatic vessels) often seen on the surface of the lungs, and of the well-known dark hue of the bronchial glands. That the colouring material was not of animal nature, he inferred from its being insoluble in nitric acid. Pearson's view seemed to derive support from the well-known dark appearance of the morning expectoration of persons who habitually sit up much at night; and from the observation of Laennec, that the peasantry, but little prone to vigil, rarely expectorate dark sputa.

But the most absolute collateral demonstration of Pearson's correctness, is derived from the history of a peculiar disease to which colliers are subject. The lungs of individuals affected with this disease become so thoroughly black (*Univ. Coll. Museum*) as to resemble coal in colour; and undergo gradual breaking up from irritative and ulcerative action.† Now the carbonaceous nature of this material, having been made matter of notoriety by the experiments of numerous persons, it appeared natural to conclude that it was composed of coal dust inhaled in a state of extreme division. This notion was indeed espoused by Dr. J. C. Gregory‡, but proved to be erroneous by Professor Graham§, who showed that the material carried into the lung was none other than the soot or lamp-black formed by the combustion of the oil which the colliers use, suspended from their heads, as they work, in mines where the safety-lamp is not used. The constant exposure to the smoke of gunpowder employed for blasting has the same effect, though in a less degree.

It remains for us to add, that we entertain no doubt of the black tint, present always more or less extensively in the lungs and bronchial glands of *healthy* persons (generally speaking, in the direct ratio of their ages), being in part due to inhaled sooty matter, but believe that it is likewise in part caused by alteration of the hæmatin of blood stagnating in the capillary vessels. This opinion is, however, based on too small a number of micro-chemical examinations to lay claim to general admission.

Finally, we may observe that the relationship of true melanic cell-pigment to the constituents of the blood, though made the subject of much dogmatical assertion, is altogether unknown.

* Phil. Trans. 1813.

† The precise anatomical characters of the disease it is, of course, beside our present purpose to enumerate.

‡ Ed. Med. and Surg. Journal, No. 109.

§ Ibid. Vol. 42.

§ 5. DIPHTHERITIC DEPOSIT.

The inflammatory action giving rise to the deposits which we include under the title Diphtheritic (Διφθερη, a membrane), is certainly of special kind, though the intimate nature of its peculiarity is yet undiscovered. These deposits form on the tegumentary surfaces, mucous and cutaneous.

(*a.*) *White Thrush* (*Muguet* of the French). — The matter of white thrush forms on the mucous membrane of the mouth, fauces, æsophagus, and nasal passages, in patches of milky colour, cheesy consistence, variable size, and irregular form. Adhering closely to the mucous surface when first exuded, it gradually becomes more and more easily separable; if artificially removed, the subjacent surface looks slightly hollowed and somewhat raw, but is not abraded.

The microscope exhibits molecules; cells of oval, spherical, or elongated form, with or without nuclei; epithelium cells, in more or less abundance; and fibrils. These fibrils, almost transparent, of delicate and sharply-defined outline, of cylindrical form, generally uniform in thickness, but sometimes swollen irregularly, and occasionally bifurcated, are not affected by water, acetic or nitric acids, or alkalies, but dissolve in sulphuric acid. Hence it appears obvious that this substance is in part entophytic; but it is only *secondarily* so, — the rapid development of fungi depending on the constitutional state, or, perhaps, upon the chemical condition, of the local secretions. The smallest cells are probably sporules.

There is no structural difference between the matter existing in the white thrush of children, and that appearing on the mucous membrane of the mouth in adults towards the close of lingering chronic diseases, especially phthisis. But it has appeared to us from numerous observations, that it is less prone to become entophytic.

(*b.*) We have examined with some care the white material of cheesy consistence which forms, in certain states of the constitution, on blistered surfaces, kept open by irritant ointments, and find no particular difference between it and the similar produce of mucous membrane. Entophytic formation occurs here.

ORDER II.—GROWTHS.

§ 1. Growths possess texture which differs in physical characters from all natural tissues, the arrangement of their septa and loculi being, among other things, distinctive of themselves. They differ, further, from natural structures, in a total deficiency of modelling faculty; they enlarge in all directions indifferently, careless, as it were, of the mechanical mischiefs their presence may inflict. They are composed of evanescent vegetating cells, incapable of propagation by artificial inoculation into the tissues of the individual producing them.

§ 2. The existence of structure in the order Growths is apparent on superficial inspection. And there is one unfailing characteristic of this structure, as displayed to the naked eye; it consists of *a stroma and an interstitial matter occupying its meshes.* This, which is the most striking peculiarity on the surface of some tumours (enchondroma, colloid cancer), is much less evident in others (milt-like variety of encephaloid, many specimens of simple scirrhus); but in these latter it is clearly disclosed by slight maceration. And the want of a clear definition at first of stromal and interstitial parts depends, not on their non-existence, but on the more than ordinary similarity in physical characters of both. Generally speaking, in truth, there is a very obvious difference in this respect: the stroma of fully developed colloid has the aspect of cellulo-fibrous membrane, opaque and close; its interstitial matter all the outward appearances of a jelly-like substance; in enchondroma, the interstitial matter, resembling jelly of a different tint, is enclosed in a stroma, in many cases formed of laminæ of bone. But, on the other hand, in some cases (as those referred to), there is no such obvious difference in the visible character of the two divisions, as they may be called, of the growth. In yet other cases, again, the outward characters of the stromal and interstitial parts differ in colour, transparency, density, tenacity, when roughly examined, and yet their intimate constitution is almost identical; this is the case in fibrous tumours.

In the majority of Growths, the stromal substance encloses spaces inclining to the spherical form, a form most distinct in enchondroma, colloid cancer, and fibrous tumours; only imperfectly seen in encephaloid; almost completely absent in simple scirrhus and in erectile growths. The manner in which the sphericity of the loculi is produced will be considered further on.

Another element of Growths, which is visible to the naked eye, or may be rendered so by means of injection, is blood-vessel. In varying proportions all Growths possess vessels, which may be limited to their stromal substance, or permeate both stromal and intrastromal substances. These vessels are in part those of the textures invaded by the new formation, in part adventitious products.

Lymphatic vessels and nerves are occasionally found within the area of a Growth; but there is no evidence that they are ever of *new* formation.

§ 3. The ultimate essential elements of tumours are granules, molecules, cells, free nuclei, and fibrils. With these elements are accidentally associated Precipitates, Deposits, Exudation-Products, and certain of the simpler Pseudo-Tissues.

(*a.*) The elementary granule is spherical in shape, flattened or amorphous; averages in size $\frac{1}{10000}$th of an inch; and is seated in the interior of cells, or on the surface of fibres, or is free. The molecule is too minute for measurement.

(*b.*) Some portion of the substance of all

Growths consist of hollow vesicular bodies or cells. The quantity of these cells varies extremely in different genera of Growths; constituting the greater part of the mass of simple sarcoma and of enchondroma, abundant in colloid cancer, they are comparatively rare in scirrhus, and may be sought for in vain in the main substance of fibrous tumours.

In form the cells of Growths are spheroidal, as in sarcoma; or ovoid, as in enchondroma; and plump, or flattened, and discoid, in proportion to the abundance of their contents.

In respect of size they vary within wide limits, from the simple fact that it is the nature of some to go on increasing in bulk (for instance, the cells of colloid and of enchondroma), of others to retain persistently the dimensions originally acquired. This anatomical distinction is connected with a very important physiological difference in the mode of increase of Growths. We do not depart much from the truth in assigning $\frac{1}{4000}$ and $\frac{1}{800}$ of an inch as the extreme measurements of these bodies. Further, the cells of the same Growth vary in size, independently of endogenous enlargement.

Cells are either set beside each other, and cohere by their contiguous walls, or they remain free.

The thickness and transparency of the wall of cells vary; the wall may be collapsed and corrugated, or stretched and smooth; the nucleus (when this exists) of the cell may be distinctly parietal or not.

The contents of cells are of four kinds:— fluid; granules; nuclei; young cells. *Fluid*, in more or less abundance, is constantly present in sound cells; upon its amount mainly depends the plump or shrivelled aspect of these. *Granules* exist in abundance in the cells of sarcoma and of scirrhus. A free *nucleus* may be found sometimes in the cell of colloid cancer and of enchondroma. *Young cells*, themselves provided with a free or parietal nucleus, are seen in the interior of the large cells of the two Growths just named.

(*c*.) The next element requiring consideration is the *Nucleus*. Nuclei are found in the great majority of Growths; either free, in connection with cells (parietal or central), or attached to fibres. Free solid-looking corpuscles are found in the substance of scirrhus; these appear (whether generated free as they are seen, or originally connected with cells, and released by the disintegration of these) to be the germs of future cells. Of the parietal and central nucleus enough has already been said. The slightly granulated look of the fibres of Fibrous Growth depends on the permanent character of their nuclei, which appear set superficially in their substance. In whatever condition nuclei exist, they are distinguishable commonly by their comparative opacity; this is rendered more obvious by acetic acid, which increases the transparency of cell-walls, or by ioduretted solutions, in consequence of the tendency of nuclei to absorb coloured matters.

(*d*.) *Fibrils*.—Fibrillar substance occurs in Growths in many varieties of form and degrees of abundance.

Peculiar fibres, of excessive transparency and delicacy, constitute the chief mass of the "fasciculate" variety of cancer. "It is impossible," as we have elsewhere said, "to look at these fibrils without being struck with their similarity to those of the buffy coat of the blood, or without conceiving the idea that blastema has been produced in connection with extravasated blood."

Fibres, differing but little from those of natural fibrous tissue, form the staple element of fibrous Growths, and are abundant in scirrhus.

An appearance of fibrous structure is produced in some Growths by linear juxtaposition of fusiform or straight caudate cells. These corpuscles have the aspect of spherical cells with two opposite points of their periphery prolonged into very minute tapering fibrils. (See *fig*. 93, p. 127.) Usually single, the fibril is sometimes bifid. The cell is obscurely nucleated, and frequently granulated; excessively abundant in sarcoma and cysto-sarcoma, appearing occasionally in hœmatoma, cystoma, angeiectoma, melanoma, and carcinoma, they cannot be discovered in fibroma. Their presence signifies that of blastema of simple plastic character; and there is no certain evidence that the proper cell of cancer (in which formation they were at one time supposed to be of peculiar significance) is capable of assuming the *perfectly* fusiform shape. Our opinion on this point has of late grown much more decided. A shapelessly caudate cell, with irregularly curved fibrils, or lateral superadded fibril, is more closely allied to cancer, and will be described with that product.

The accidental and non-essential elements of Growths belong to the other divisions of Adventitious Product. From the class *Precipitates* may be found saline matter, amorphous or crystalline, in minute quantity, or so abundant as to convert (in the instance of fibroma) portions of a Growth into true concretions. Fat occurs in the various forms mentioned in a previous page; rare in some genera, as fibroma and enchondroma; it abounds in carcinoma. From the order Deposits appear melanic matter and pus; the latter an element generated by inflammation in Growths as in natural textures. Growths, too, of one kind may (as entozoa of one species grow in the bodies of another) find a nidus for development in Growths of a different kind; cancer may thus appear within the area of an erectile tumour.

Exudation-Products exhibit themselves in the form of compound-granule corpuscles and induration-matter; while of Pseudo-tissues, there occur epithelium, cartilage, cellular, serous, fibrous, elastic, osseous, cutaneous, pilous, and dental tissues; the last three limited to Cystoma.

The elementary cells of Growths may either lie in juxtaposition, or interspaces, filled with so-called intercell substance, may

exist between them. This substance may be fluid or solid. Fluid intercell substance is nothing more than non-solidified blastema; the solid variety is amorphous, or composed of fibrous pseudo-tissue.

§ 4. The PHYSIOLOGY of Growths comprises the phenomena of their origin, enlargement, decay, elimination, cicatrization and local reproduction, — phenomena which, it appears to us, can, only by misapprehension of their true relations, be included under the head of the Pathology of these Formations.

All that is known actually, or surmised upon fair grounds, concerning the *origin* of Growths, has already been stated in our general remarks on Blastemal Formations.

The *enlargement* of Growths is effected by the reception and evolution of nutritious matter. Growths *receive* this matter from vessels; these vessels either permeate the mass generally, supply portions only of its substance, or merely reach a greater or less extent of its surface. In the first case, the growth is said to enlarge by intussusception; in the third, by pure imbibition; in the second, by both means. These distinctions are less important than they on first view seem; the perfect nutrition of the extra-vascular natural tissues proves, as a general fact, the vigour and efficacy of the imbibition-process; and in truth imbibition is at play in all nutritions, for the nutrient elements of vascular tissues must be imbibed through the coats of their vessels, and (it may be) in addition (as in the instance of the endosteal lining of the canals of Havers, and the subjacent osseous substance) through a stratum of cells. Enlargement by intussusception differs therefore from that by imbibition, in degree rather than in kind. In whichever way conveyed to the seat of Growth-formation, the nutrient material, at first fluid, is *evolved* and *appropriated* by continuous cell-generation. Now this cell-generation may be effected on an *endogenous* or an *exogenous* plan. When the plan is endogenous, the germs of young cells are contained and evolved within elder ones; these secondary cells are endowed with a similar procreative faculty; the tertiary series are in like manner fecund, and so on. Here a single cell may be regarded as the *potential embryo of an entire growth*. When, on the other hand, the plan is exogenous, the germs of new cells are not found within, but lie, and are evolved, outside old ones.

Where endogenous evolution prevails, and a cell is, potentially considered, a tumour in futuro, the perpetual production of similar cells is easily intelligible; the offspring that follows is as the parent that went before. But in exogenous Growths the continuous germination of infinite series of like cells is not readily conceived. It may be surmised (and the surmise amounts rather to a modified expression of the fact than an explanation), that when a series of cells has sprung into being, this series acts on the evolution of succeeding ones, as a natural vascularized surface is known to do on the generation of epithelium cells; the formed series so influences newly-exuded blastema (of which it constantly excites the accession), that this shall produce a new series of cells similar to itself. But, however the perpetuation of like cells be understood, be it remembered that the thing itself has its limits; for, as we have just seen, deposits may appear in Growths, pseudo-tissues are among their frequent constituents, and a growth of one kind may establish itself a nidus within the area of another generically dissimilar.

Elder cells thus seem (within certain limits) to cause the increase, and regulate the qualities, of younger ones. Younger cells are, on the other hand, more or less active agents in effecting the destruction of the elder ones: less so in endogenous Growths, where the elder may increase materially in size (as their contained brood multiplies), and acquire thickened walls; more so in exogenous Growths, where such enlargement of cells is not witnessed, and where the production of young is coeval with the disintegration of old ones.

Such are the modes of production and increase of cells, considered in their general relations to themselves and to the mass they form. We must now view cells as individual existences, and inquire into the process by which they are each developed; and our knowledge of this process is as yet limited and unsettled. The *spherical cell* appears to be produced on three distinct plans. (*a.*) Granular matter, precipitated from the fluid blastema, accumulates sufficiently to form a minute solid body (cytoblast or nucleus), from and around which the cell-wall forms. (*b.*) The cell is a molecular hollow body from the first, and, as it grows, produces within itself, or in its wall, a secondary body, the nucleus, — the cytoblast of a future cell. (*c.*) The cell is, from the first moment of its existence, complete in all its parts, consisting of a cell-wall, a nucleus, and fluid contents; its development consists in the progressive and justly-proportioned increase of all these elements. The *caudate cell* is held to arise (as already hinted) from the prolongation of opposite points of the wall of a spherical cell; but there is no proof that cells may not exhibit this shape from the first moment they are possessed of form at all. Lastly, the *elementary fibre* is held to be formed in three different modes. (*a.*) A spherical cell having undergone elongation so as to become caudate, loses by still increased elongation and flattening, the characters of a hollow cell altogether; a nucleated fibre is the result. (*b.*) Elongation and linear juxtaposition of nuclei effect the formation of fibre. (*c.*) Or, it is held, fibres form as such from the first moment shape is assumed; no cell, or nucleus-stage having pre-existed. All these points are yet *sub judice*.

The plan of enlargement and mode of arrangement of the ultimate elements of

Growths seem to exercise a very distinct influence on the structural character of the mass as visible to the naked eye. The locular aspect of their divided surfaces, for instance, we fully believe to be dependent on such influence. In the case of Growths enlarging on the endogenous plan, it is obvious that the juxtaposition of successive round cells within a containing or parent cell must cause this to retain its spherical outline, until it has enlarged sufficiently to become visible with the naked eye; and further, that if several of these enlarged cells be placed round a common centre and beside each other, the general form of the area they cover must be spherical. And so we find that it is precisely in enchondroma and in colloid cancer, distinctly endogenous formations, that sphericity is most decided. The thickening and fibrous deposition, which take place both in the walls of enlarged cells and in the intercell substance, contribute further to the deceptive appearance of encysted structure. In masses which enlarge on the exogenous plan, the spherical character in the loculi is much less apparent. In scirrhus, and in many specimens of encephaloid, it is not to be clearly descried; the predominance of straightly-fibrous arrangement of the stroma, produced by the presence of real fibrous tissue, of fusiform corpuscles, &c., accounts for this. But even in Growths of this class, the original rounded form of the elementary constituents tends to impress upon their larger divisions, as these do upon the entire mass, the spherical shape. Accidental circumstances, of course, are liable to affect this; but the internal locular arrangement of fibrous tumours shows that those circumstances may be only partially effectual.

The locular character (under the title of "encysted") has been put forward as an evidence of "malignity" on the part of the structure exhibiting it. Experience proves the notion to be untenable. Sphericity of the loculi is most obvious in enchondroma, one of the most intrinsically innocent Growths known; such sphericity is, on the other hand, totally, or almost totally, wanting in scirrhus and many specimens of encephaloid. Again, the least deleterious form of cancer — colloid, exhibits it in an especial manner; and, though modified, it is evident in those peculiarly benignant structures (considered in their essence) fibrous tumours.

The *decay* of Growths is preceded by softening of their substance; this softening, indeed, by its increase actually constitutes their decay. The change is effected by infiltration of serosity, interstitial hæmorrhage, by saturation with inflammation-products and by gangrene, either of inflammatory or simply mechanical origin. Or, there is an important class of cases, in which the softening of Growths seems analagous to that undergone by stagnating fibrin, and probably depends on chemical decomposition.

The *removal* of Growths (fibrous, cancerous, and others,) is sometimes effected by a spontaneous process, commonly comprising attenuation and rupture, or ulceration of the investing natural tissues, and gradual liquefaction of the morbid matter, which is poured through the opening; or, in less common cases, consisting of sphacelus, whereby the mass, in whole or in part, is separated from its connections.

Cicatrisation of the ulcerated surfaces of Growths is occasionally witnessed. We have ourselves seen this change occur on the proper surface of formations possessing all the characters of scirrhus.

Growths of all descriptions are liable, when removed spontaneously or by art, to be *reproduced* in the spot they previously occupied, if the removal have not been absolutely complete. The particles left behind act as attractive forces for new blastema convertible into cells, similar to those of which themselves are composed. This mode of reproduction (as it is erroneously called, for it is nothing more than enlargement, facilitated by removal of pressure of pre-existing substance) occurs with Growths of all kinds, cancerous, sarcomatous, fibrous, fatty, enchondromatous, erectile, &c. But it would appear that in some cases of surgical removal, when the whole mass has, as is presumed, been extirpated, a new growth vegetates in its place. The difference of the cases is often rather apparent than real: we have distinctly found the germina of cancer in tissue, reputed healthy, surrounding a cancerous mass; and it is manifest that such germina, though invisible to the naked eye, may, quite as readily as a fragment of diseased tissue of even considerable size, act as the efficient agents of new development. When, independently of this mode of generation, the disease returns in the seat of its former growth, the occurrence must depend upon the continuance of that depraved state of the blood which is fitted to supply the necessary blastema, and likewise, possibly, upon some peculiar state of vessels of the part favouring its exudation here rather than elsewhere.

In other cases, hardly has a growth been removed from one place, when a mass of the same kind appears in some distant and apparently unconnected part of the body: this occurrence, which is especially observed in the case of cancer, is termed its "distant reproduction," and is explicable in two ways. The newly discovered growth may have existed previously to the extirpation of the old one, and having simply acquired additional activity, so become obvious, after that extirpation. Or the new growth may really have first appeared subsequently to the removal of the old (this we believe to be rare): in this case the simple explanation is that the vitiated state of the blood, proper for the supply of the necessary blastema, continues; and this blastema is poured out in some other part of the frame, the original tumour no longer existing to attract its deposition within or around itself.

§ 5. The chemical study of Growths is yet in its infancy. Müller's division into three chemical classes, the albuminous, the gelatinous, and

the fatty (rational enough, chemically considered,) fails pathologically. Growths of very opposite tendencies and attributes are to be found in the same chemical class; thus the most deleterious forms of cancer are albuminous, while sarcoma (per se most innocent) is the same in its chemical basis.

(*a.*) In the albuminous growth the other forms of protein are frequently present as essential ingredients; the term growth of protein-basis appears therefore more strictly applicable. A matter said to be allied to ptyalin has been found in this class. Continued ebullition scarcely furnishes a trace of gelatin; and when some such trace does appear, is probably derived from natural gelatinous textures accidentally connected with the morbid mass.

(*b.*) Growths of the gelatinous class are almost completely reduced to jelly by boiling. The gelatin yielded is either of the common species, as in fibroma, or of the variety known as chondrin, and first detected by Müller in enchondroma.

(*c.*) In the fatty class, the fatty matter is chemically the same as that of ordinary adipose tissue (e. g. in lipoma); or it is more or less closely allied to cholesterin (e. g. in cholesteatoma).

The fatty particles which exist in almost all Growths, even of the albuminous kind, and which do not form the essential part of the mass, are not contained in cells, as in true fatty Growths, but exist in the various forms enumerated in a former passage.

Carbonates, hydrochlorates, and phosphates of the alkalies and earths are the inorganic salts most commonly and largely associated with the animal constituents of growth.

§ 6. The Pathology of Growths embraces the subjects, first, of the morbid changes arising in, or in immediate connection with, those formations; and, secondly, of the various conditions of the system which precede, accompany, and follow their evolution. Their pathology may, in other words, be regarded as *local* and *general.*

(*a.*) *Local.*— Under the head of physiology we have considered briefly the various changes arising in Growths, as essential phenomena of their complete development; and which, however they may be regarded as morbid in respect of the system generally, are, on the part of the adventitious mass in which they take place, evidences of natural progress. But there are numerous changes occasionally occurring in Growths, that are actually morbid in essence in relation to the substance of the new product itself; and others of a similar character which are produced in the surrounding tissues. These two classes of changes (which can only be glanced at here) constitute the materials of the Local Pathology of Growths.

1. The changes observable in the substance of Growths, and which signify a departure from the regular process of evolution, are:— congestion; infiltration with blood or with serosity; hæmorrhage, and in consequence of these states, various forms of discolouration; inflammation; mortification; and the deposition within or upon them of some adventitious material foreign to their nature. In fact, the chief morbid changes occurring in the natural structures may arise in these formations.

2. The effects produced by Growths on surrounding tissues are *mechanical* and *vital.*

The *mechanical* variety comprises detrusion and various other displacements; condensation; discolouration; infiltration; blocking up of cavities; interference with the motion of fluids, &c.

The detrusion produced by Growths may be simple, expansive, or causing pedunculation, a peculiarity observed when certain Growths, endued with little or no tendency to infiltrate the parts around, originate between a mucous or serous surface, and a hard, resisting tissue. And this for obvious reasons; with the progress of their enlargement the distention they induce does not equably affect all surrounding parts (because the resistance of these is unequal), but acts especially upon the least resisting structures. As they enlarge, they carry these structures before them, until themselves eventually protrude sufficiently from their precise seat of origin to leave a sort of process of the membrane they push before them, acting as a stalk of attachment to the place of their original connection.

A growth thus pedunculated is practically known as a *Polypus*, a term extremely injudicious, as it leads the observer to neglect the important matter of the *nature* of the tumour, and to regard a mere accident of shape as an essential feature.

The *vital* effects are rarefaction; condensation; atrophy; hypertrophy; inflammation, with its results — adhesion, softening, induration, ulceration, mortification, perforation, effusion of blood, enlargement of vessels, &c.; and, most important of all, infiltration of the surrounding tissues with matter similar to that composing the new growth. This last effect occurs (as we believe) in connection with no growth except cancer, and constituting one of the most evident pathological and nosological distinctions between cancerous and other allied formations, will be presently examined.

§ 7. The nature of this work will not admit of any extended observations on the general Pathology of Growths, but some prominent facts can scarcely be passed over in silence.

The *conditions of localization* of Growths are curious, and for the most part inexplicable. The following propositions may be laid down concerning them:—

(*a.*) The tendency to become the seat of Growths, as a class, varies greatly in the different tissues and organs. Thus, while cellular tissue is their peculiarly favourite site, fibrous texture but rarely affords them a nidus. Again, the mamma, the ovary, the uterus, are frequent, the lungs and brain much less common, sufferers.

(*b.*) The tendency to become the seat of

Growths, as a class, varies in the different parts of organs. Thus the pyloric end of the stomach suffers more frequently than the rest of the organ; the epididymis than the body of the testis.

(*c.*) Certain organs, and certain parts of organs, have an excess of tendency to the formation of certain *special* Growths. Thus the uterus, the mamma, the stomach, the liver, are peculiarly prone to cancerous, as distinguished from other forms of growth; the bones are the chosen seat of enchondroma. And, again, cancer does not form indifferently in all parts of the uterus, but tends especially to invade its neck; while fibrous tumours affect a preference for the body of the organ. The large intestine is a tolerably common seat of cancer; the small is very rarely implicated.

(*d.*) Growths of different kinds exhibit different degrees of compatibility as co-existences in the same body. Some Growths, as Cystoma and Carcinoma, are sufficiently prone to appear in the same individual; others, as Fibroma and Carcinoma, are rare co-existences; none are actually incompatible, either as unconnected co-existences, or as developments in each other.*

Sex influences the site of Growths. The renal organs of the male suffer more frequently than those of the female; the converse is true of the genital organs. In like manner, age has its influence. But on the whole, the causes of these peculiarities of seat are unfathomed.

A Growth having once been developed, may pursue an anatomical (or better, topographical) course, of three different kinds. *First*, it may remain solitary and alone till the death of the individual in whom it exists, no other organ or tissue than that originally affected becoming involved by similar disease. This is frequently observed in the case of enchondroma and of cystoid tumours, occasionally of fibrous, and even of cancerous Growths.

Or, *secondly*, a morbid mass originates in some particular site, whence it seems to spread as from a centre to a multitude of parts; the latter are said to be the subject of *secondary* Growths. The mechanism of this propagation differs according as parts adjacent to or distant from the primary formation are the consecutive sufferers. (1.) When circumjacent tissues become the seat of secondary development, this is either the result: — first, of progressive and direct infiltration of those tissues by the morbid matter; or next, of infiltration spreading to those tissues through the medium of the proceeds of common inflammation (induration-matter) previously deposited among them, in some instances effecting adhesions between parts not actually adherent to each other in the natural state; or, lastly, possibly of infiltration arising in some unexplained way, through the influence of a part simply placed in juxtaposition, and not continuous (either naturally or accidentally) with the tissues primarily affected. These modes of secondary implication are exemplified by cancer alone. (2.) The formation of secondary Growths in distant organs, where an effect of pre-existing disease elsewhere, seems only intelligible as a result of transmission by the lymphatic or vascular systems. Cancerous, and perhaps fibrous tumours, give rise through both these routes, to secondary development. As respects the lymphatic glands in communication with a cancerous mass, they may themselves become cancerous, while the vessels leading to them are either filled with morbid matter of the same kind, or perfectly free from all anatomical change. Now when the tubes are themselves loaded with cancerous substance, and are, for example, traceable so loaded even to the thoracic duct (A. Cooper; Hourmann), without any evidence existing of the matter being a product of their own tissue, the implication of the lymphatic system, is evidently the result of absorption. But when (as is more commonly the fact) the cancerous state of the glands is unassociated with similar contamination of the connecting tubes, it is not thus so plainly and satisfactorily explicable. Still it is probable that in the majority of cases the principle is even here the same; but that the mode in which stagnation of absorbed particles takes place differs. In other instances it is possible that cancerous development in the glands may be effected as in an independent and original centre of production, and not through a process of absorption or other direct mode of influence of pre-existing Growths. These notions are put hypothetically; but they appear to me more likely to be well founded than those usually tendered. Nevertheless if contamination be admitted to arise as a result of absorption in *some* instances, the inference appears necessary, that it shall occur in *all* cases; inasmuch as a process of nutrition, accomplished in the usual way, is constantly going forward in morbid Growths. Now, as matter of fact, such contamination does not always ensue, and, above all, does not commence from the earliest period of evolution of the previous growth. Here seems to lie a serious objection to the doctrine of lymphatic absorption. But the absorption is only thus shown to be of a kind which we may, for convenience sake, call *unproductive;* and which may be assimilated to that taking place from abscesses, in cases where no pus, with its sum of natural properties, finds its way into the circulation. That the pus-corpuscles undergo, in such cases, dis-

* It is true we have never ourselves seen cancer within the substance of a fibrous tumour; but there is no *à priori* motive for disbelieving the possibility of such localization, and competent persons affirm they have seen examples of it. Although *tubercle* is not, properly speaking, a growth, it may be well to observe here (as we first showed eight years ago), that this product and cancer rarely co-exist. Among 104 cases of death from cancer, there were but seven in which the anatomical character of phthisis was present. The age at which the two diseases are most prevalent will, to some extent, but not wholly, explain this result. (See Nat. and Treatment of Cancer, p. 185.) On the other hand, the diseases by no means absolutely exclude each other; cancer and tubercle may form in the same organ.

integration and alteration, is matter of physical demonstration — changes which divest them apparently of their pathological properties. On analogy, which seems in nowise strained, we may then admit that disintegration of the elementary cells of the morbid Growth is the cause of the occasionally *unproductive* character of cancerous absorption.* When, on the other hand, secondary Growths form in localities free from direct lymphatic communication with the seat of the primary formation, there can be no doubt (although the productive elements have not yet been found *in transitu* with the circulating blood) that the venous system acts as the agent of translation of such elements from the one to the other site. In the instance of cancer the following arguments may be adduced in favour of this notion. α. "Cancerous matter exists in a multitude of cases in the veins of the diseased part; now this is obviously a most favourable circumstance for its circulation with the returning blood. β. The rapidity of the successive development of the disease in different organs, sometimes observed, seems only producible by the agency of a fluid which, like the blood, pervades them all. γ. The liver and lung, the two organs in which foreign bodies introduced into the circulation are almost invariably observed to stagnate, are by far the most frequent seats of the secondary development of carcinoma. δ. The parenchymatous viscera and the bones, the precise structures most frequently affected with secondary abscess, are those peculiarly liable to secondary cancer. ε. In respect of both morbid products, the liver and lungs stand at the head of the list for frequency of implication. ζ. Secondary abscesses affect a special preference for the peripheric strata of the viscera; so likewise do secondary cancers. In the instance of the lung, I believe this readily explicable, by the fact that the majority of the ultimate ramifications of the pulmonary artery reach the periphery of the organ before becoming continuous with the capillaries, wherein stagnation must occur. η. Double organs are very rarely the simultaneous seats of primary abscess; in cases of secondary abscess both invariably suffer: the same propositions hold good of cancer. ϑ. Secondary cancer in the liver and lung occupies the same elementary seat (the lobules) as the pus of secondary abscesses."* Some apparent objections to the doctrine here upheld are examined and (as we believe) refuted in the same place.

Or, *thirdly*, in certain cases where numerous parts are found to be the seats of tumours of the same species, it is more than probable that the development of these tumours has been simultaneous, and each mass been evolved independently of its fellows. There can be no doubt, for instance, that internal cancer is frequently described as secondary to external cancer (especially when the latter has been removed with the knife, and the former has not manifested its existence by symptoms until after the operation), where no proof of the two Growths not having originated at the same time can possibly be adduced. The same is true of Fibrous Growths.

The *inoculability* of Growths has not been maintained except in the instance of cancer, and, even in respect of this product, upon very imperfect evidence. Experimental results may be cited against (Dupuytren), and in favour of (Langenbeck), the transmissibility of the disease by inoculation; while, on the other hand, we learn from M. Gluge that his attempts generally failed utterly, and in rare cases appeared to succeed. Theoretical considerations, repudiating, as they do, the idea of the constant inoculability of cancer-elements in organisms of all varieties of morbid aptitude, nevertheless do not wholly oppose the notion, that where *constitutional predisposition* to cancer exists in an animal, the germinal element of that product, introduced into its blood, may prove prolific. Unless this constitutional state exist, "even the actual elements of cancer only manifest themselves as simply irritative agents, the perfection of the seed is not enough to secure the development of the plant; the soil, in which it is sown, must be capable of feeding it." Perhaps these views furnish a clue to the contradictory statements of experimentalists.

§ 8. Clinical observers of disease have long been aware that certain Growths are of evil, others of innocent, tendency; that they are "malignant" and "benignant." Morbid anatomists have sought to connect definite and invariable structural characters with the possession of one or the other tendency; and their search has been vain. Micrologists are divided on this question; some affirm that "malignancy" depends on the presence of a special cell; others deny the distinctiveness of microscopical elements.

We, for our own parts, believe that the qualities of a growth cannot be determined by the characters of its cell. We have known Growths, which had destroyed life with the cachexia of cancerous disease, and clearly exhibited the local progress and naked-eye characteristics of encephaloid; Growths which, nevertheless, were composed of non-nucleated cells undistinguishable from those of common exudation-matter. Nor do we be-

* Absorption of cancerous matter artificially induced, would *à priori* appear likely to prove of the *unproductive* kind, as disintegration of the primary particles of the growth must, in all probability, form a stage of the absorptive process. The question is rendered one of practical interest by the prospect held out of removing these tumours by the ingenious system of pressure invented by Dr. Arnott. It is clear, in truth, that if that system only lead to the translation, from one part of the frame to another, of elements endowed with the faculty of unlimited germination, the benefit obtainable from it is more apparent than real. Whereas if, while that system causes their entry into the circulating fluids, it deprives their elements of all productive power, and leaves them in a condition fit for excretion as effete particles, a perfect *cure of the disease* is effected by the *removal of the tumour.*

* Nat. and Treatment of Cancer, p. 106.

lieve that any mode of association of cell and fibril (at least any mode *now* known and understood) can be considered distinctive of carcinoma. On the other hand, we believe that Growths of evil tendency have a manner peculiar to themselves (ascertainable by naked-eye observation) of accumulating in the tissues. We refer to accumulation by *infiltration*. The nature of infiltration is easily explained. The elementary molecules of the morbid matter, instead of accumulating round a central point equally in all directions, and pushing aside the tissues amid which they are deposited, spread between the primary elements of those tissues on every side. In proportion as this extension of the morbid matter is accomplished, interference with the healthy process of nutrition takes place. The effete particles of the natural tissues cease to be replaced by similar ones; and an appearance of conversion ("transformation" or "degeneration") of a natural into a morbid structure is worked out. But if the nature of the phenomenon be simple, its *cause* is obscure. Why it should occur (as we conceive it does) in the instance of cancer alone, and why peculiarities so important as those of cancer, in respect of *general* influence on the system, should appear to hang upon the existence of a *local* pathological attribute, in nowise remarkable, strictly considered *per se*, is a difficulty which facts are wanting to explain away. Speculatively, as we have formerly said, "we must look elsewhere for an explanation of the evils practically connected with infiltration, than to the mere physical phenomenon itself, — in a word, we must seek elsewhere some condition of which the process is but a consequence or involution. But the natural place to look for this condition is in the tissues themselves, which undergo infiltration; and in these — in some special morbid change within them — must reside the source and origin of the process. And this view is confirmed by the fact, that there is nothing in the mode of vegetation of cancer itself to explain why it alone, among vegetating new formations, should possess the power of infiltrating the natural tissues."

We are aware that the property of infiltration has been ascribed to other *Growths* besides cancer; that fibrous tumours have, for instance, been said to affect circumjacent tissues in this manner. But we are persuaded, from close examination of such alleged cases, that infiltration with common plastic matter (the produce of inflammation arising from irritating pressure on the part of the tumour) has been mistaken for infiltration with substance identical with that of the fibrous growth; and that the distinction is nosologically sound.

On the grounds just set forth, we propose to divide the order Growths into two sub-orders — the Non-Infiltrating and the Infiltrating.

SUB-ORDER I.—NON-INFILTRATING GROWTHS.

The genera in this sub-order may be arranged according to chemical composition — the protein compounds, fat and gelatin, being severally the predominant element.

Of Protein-Basis.

§ 1. HÆMATOMA.

Blood effused into the tissues may be either (*a*) absorbed wholly or partially, or (*b*) not absorbed.

(*a*) 1. If the blood be absorbed wholly, no vestige of the hæmorrhage may ultimately be traceable, even in the condition of the tissue amid which it occurred; or (as is more common) even after the total removal of the blood-elements, some slight puckering, changed density, or changed position of the proper texture of the organ (of the brain, for instance) reveals the fact that hæmorrhage has occurred. In either case, blood has escaped from the vessels without leaving even the potential elements of a growth behind it. 2. Partial absorption acts commonly upon the watery and colouring matters of the blood, the fibrin alone remaining: this fibrin (fibrinous hæmatoma, from αἵματωμα, blood-tumour), may form a single mass, as is usual in the parenchymata, or several fragmentary parcels, as happens generally in the serous cavities. Partial absorption, in a class of rarer cases, acts first upon the fibrin; the effused blood becomes more thin and aqueous, and sometimes (spreading by infiltration and endosmosis amid the surrounding textures) is thence eventually absorbed: here no residue, referrible to the present head, remains behind.

(*b*) When not absorbed, blood either (1) excites inflammation and its consequences; or (2) remains stationary in a fluid condition; or (3) assumes the characters of dark grumous semi-coagula; or (4) undergoing inspissation from deprivation of its watery parts, a firm coagulum, growing daily more solid, remains behind: in this last instance we have a coloured hæmatoma.

A hæmatoma is then a fibrinous mass, coloured or not, arising from hæmorrhage.

Before us (Univ. Coll. Mus.) lies a colourless hæmatoma of the spinal meninges in the cervical region, the result of a blow. Its size is that of a walnut; it is of pale straw-colour, homogeneous on superficial view, but finely granular when closely inspected. Hæmatoma may, however, be coarsely loculated; the walls of the loculi being solid, the contents more or less fluid, or gelatiniform-looking. Such tumours (while unchanged in characters) exhibit microscopically the qualities of fibrin, — fibrils gelatinizing with acetic acid,— amorphous fragments, granules, and molecules. Their colour varies; it may be of deep yellow, somewhat buff, tint,— and commonly is so, in the spleen and kidney, for instance. Their chemical reactions are those of fibrin.

The surface of a hæmatoma is smooth; a coating of epithelial structure, rapidly form-

ing, gives it this character. A hæmatoma is rarely encysted; for though nothing is more common than the formation of a cyst round effused blood (apoplectic cyst) as a general fact, yet this process is rarely witnessed, where the progress of absorption has been of the kind to produce a hæmatoma.

Hæmatomata may probably form wherever blood, thrown out from the vessels, is retained. Thus (1) they are seen in the serous cavities,—as the peritonæum and pleura, where they have more than once been found in the stages of transition; and in synovial cavities, where, as John Hunter long since maintained, they frequently form the so-called "loose cartilages" of joints. (2) Amid membranous structures,—as for instance, under the choroid coat, where they have been frequently mistaken for carcinoma; into the great cavity of the arachnoid (Univ. Coll. Mus.)—a not uncommon seat; between the arachnoid and dura mater of the skull, where, we feel positive, they have occasionally been the origin of minute fibrous tumours; under the mucous lining of the uterus, where a similar destiny sometimes awaits them; under the periosteum, either when the blood has flown through the influence of external injury, or through the influence of causes, partly traumatic, partly spontaneous, as in that singular affection of new-born infants—cephalhæmatoma.—(3) In parenchymatous organs, as the brain, the spleen, the kidneys, the lung (in all of which we have repeatedly seen them), and more rarely in the mamma, where they have often, clinically, played the part of cancers.—(4) In the cellulo-muscular structures of the limbs, as the result of contusions or spontaneous hæmorrhage.—(5) In the proper substance of certain new products, especially encephaloid cancers.—(6) In cavities accidentally formed in the tissues, as in tuberculous cavities in the lung. (Univ. Coll. Mus.)

Various changes of deep interest may occur within the substance of a hæmatoma. Unsupplied with vessels, as it commonly is, it cannot be the seat of interstitial hæmorrhage; but blood may nevertheless infiltrate its substance derived from the ruptured vessels of surrounding textures,—just as extra-vascular tissues may become infiltrated with exudation-matter produced by inflammation, not *in* them, but *beside* them.* Saline precipitation is a common occurrence; such is often the origin of ossiform particles or masses in the brain; of similar masses in advanced cephalhæmatoma†; and such (as elsewhere shown by us) is almost invariably the source of free calcareous and ossiform products in cancer: the changes concerned in the production of a phlebolith are one by one gone through. That melanic pigment may form in hæmatomata appears extremely probable, from certain observations which we made several years ago on some specimens of melanic tumour; full reference to these will be found in the section on Melanoma. We have in a previous section spoken of the doubt still hanging over the question of the possible evolution of simple effused blood into Formations of definite structural characters. The question appears to be all but absolutely decided in the affirmative by a tumour now before us (Univ. Coll. Mus.), in the substance of which the transition from the characters of hæmatoma to those of fibrous tumour, is perfectly traceable in point of colour, consistence, and textural arrangement. Bone-formation may take place from blood effused in localities where a tendency to such formation naturally exists, and where formative life is active. Thus, in the instance of sub-pericranial cephalhæmatoma, the smooth gelatinous-looking membrane, which invests the blood, may become so perfectly ossified, that it has, in this state, been evidently mistaken by some observers for the outer table of the bone, and a figment, in the shape of *interstitial* or *diploic* cephalhæmatoma, invented to meet the difficulty. Even in the *centre* of the fibrinous residue of this effused blood actual bone has sometimes been seen.

* A remarkable example of hæmorrhage into a hæmatoma of the brain lately occurred in our wards in University College Hospital.

† See this word, Cyclopædia of Surgery, vol. i.

Concerning the vascularization of blood in substance we have already given our opinion. Hæmatomata in the brain have been found distinctly vascularized in cases where there was no evidence that plastic lymph had been added to the extravasated blood; and M. Louis' description, already referred to, of a vascularized coagulum in a tuberculous excavation of the lung is peculiarly satisfactory.

Blood retained in its proper canals may coagulate and undergo various changes. In the arteries, cellulo-fibrous evolution and calcification occur in stagnating blood without the intervention of an inflammatory process: in the veins we have seen vascularized coagula injected; and the formation of phleboliths and arteroliths illustrates saline precipitation. Vascularized coagula in the heart have been described by Rigacci, Burns, Bouillaud, and others.

§ 2. SARCOMA.

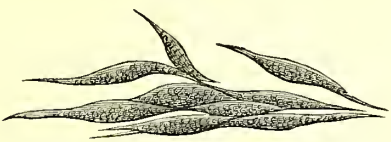
Simple sarcoma (σαρξ, flesh), or cellulo-vascular growth, presents itself as a mass of variable dimensions,—those of a hazel-nut and of a cocoa-nut are the extremes we have seen. Of oval or, less commonly, spherical outline, its surface may be even and tolerably smooth, or nodulated (U. C. Mus.). Sarcoma is particularly elastic; varies much in consistence and density; breaks sharply under the nail, in the direction of its fibres; is rather crisp than tough, unless in the site of its cellulo-fibrous locular walls; exhibits on section a tolerably smooth, glossy, semi-transparent surface, such inequalities as exist depending upon the unequal elasticity of its containing and contained elements; is free from greasiness, either to the look or feel; is usually of pale yellowish or buff colour in the main, presenting here and there reddish or more rarely lilac-tinted spots, or striæ, or

(it may be) a more or less uniform red hue; and yields on pressure a small quantity of slightly glutinous, thin, yellowish, transparent fluid. The vessels of sarcoma may be pretty equally distributed through its substance, or set in a sort of patch-work.

These growths are essentially disposed to become encysted. Their cyst, vascular and cellular like themselves, may be fibrous in part, and is formed both of natural cellular tissue condensed, and of exudation-matter solidified. This secondary or pseudo-cyst adheres closely to their surface, and *appears* continuous with the cellular and thin, or fibrous, thick, and opaquely white, membranous septa of the growth.

Molecular matter, granules, spherical, oval, and caudate cells, and fibres form the ultimate constituents of sarcoma. Its spherical cell seems to us identical with the common inflammatory exudation cell. (See Pseudo-Tissues.) The oval cell, of larger size (measuring .00073 of an English inch and upwards, according to some estimates by Müller), is provided with a dark, well defined, but small nucleus: such cells are sometimes enclosed within a mother cell-wall of proportional dimensions, and afford clear evidence of endogenous procreation. Slightly elongated at opposite ends, as they sometimes are, they eventually pass into the state of caudate or spindle-shaped cell (*fig.* 93). Such caudate cells are either arranged in linear juxtaposition, as above; or they are scattered loosely through the mass. They are not plainly nucleated, as a general rule; but acetic acid brings out a parietal nucleus. They seem to pass by an easy transition into fibres; and eventually these fibres acquire for the greater part the characters of those of cellular tissue, but occasionally of fibrous, and yet more rarely (we have seen this) of elastic texture. The molecular and granular matter of sarcoma is probably in part fatty; but oil-globules are of rare occurrence.

Fig. 93.



Caudate cells from an albuminous sarcoma of the conjunctiva. (After Müller.)

Sarcoma is mainly composed of albumen; but (especially when a cyst with thickened processes exists) will yield a small quantity of gelatin by boiling.

There are probably few sites in which sarcoma does not form. We have seen it in the cellular tissue under the lower jaw; in the substance of both maxillæ (whence it has frequently been removed with successful results); under the periosteum of the long bones, or (more rarely) in the actual substance of these; in the mamma; in the eye; in connection with fibrous textures, as the dura mater, &c.

Hæmorrhage, calcification, and suppuration occur in sarcoma; the latter with great rarity. We have never seen cancer within the area of a sarcoma.

Condensation and detrusion of surrounding parts are mechanically caused by this growth; it has no intrinsic tendency to affect those parts otherwise, though inflammatory changes may, from over distention, be induced among them.

§ 3. CYSTOMA.

See Pseudo-Tissues; Serous.

§ 4. ANGEIECTOMA.

Masses of variable size composed of dilated and elongated vessels may be described under the name of angeiectoma (αγγειον εκτεινω). They are rare productions, and seem essentially produced by dilated hypertrophy of the small vessels, venous or arterial.

A tumour of this kind has been figured by Dr. Carswell, (Fascic. Melanoma, pl. ii. fig. 2). It was sunk into the substance of the brain, but evidently in connection with the pia-mater. "The bloodvessels of the pia-mater passed into it, and constituted by far the greater part of the tumour. They became tortuous in its substance; some of them, being nearly a line in diameter, were reflected backwards at their extremities in the form of irregular intertwined bundles, towards which two or three small arteries, coming from the pia-mater, were seen to distribute themselves." Lobstein (Anat. Path. t. i. p. 461) describes a similar mass formed of a venous plexus. In both these cases the veins contained, and were bathed in, melanic liquid. Dr. Warren (On Tumours) figures and describes a case of congenital tumour composed of greatly dilated and knotty veins seated in the neck.

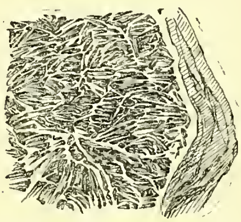
There is a species of epulis which appears to be composed of dilated and hypertrophous arteries. Cruveilhier (Anat. Pathol. livrais. 33.) describes certain tumours on the surface of the skull, pulsatile, erectile, and the seat of blowing arterial murmur, which had eroded the bone; there were similar formations in the external soft parts; they were composed of dilated "arterial capillaries." A man was admitted some years ago into Univ. College Hospital (Mus. Model 2854), under Mr. Liston, having a series of pale red, knotty tuberosities, extending from the left orbit to the occiput, pulsatile, erectile, and the seat of blowing murmur at a particular point. Death ensuing, Mr. Marshall examined the larger of the series, and found that it consisted in the main of dilated and tortuous arteries, with intervening fibrous tissue and granular fat; large straight veins existed, and one or two of these uniting at obtuse angles, passed between (but did not communicate with) the arterial branches at the site of the blowing murmur. No true erectile structure was to be seen.

Tumours of this kind (such are many nævi, nævi verrucosi, and aneurisms by anastomosis), because *physiologically* erectile, have been

presumed to be *anatomically* so, and confounded with Growths composed of true erectile tissue.

Allied, at least in its functional characters, to angeiectoma, is the growth composed of true erectile (or cavernous) tissue. Soft, doughy, pseudo-fluctuating, pulsatile, erectile, the occasional seat of tactile fremitus and blowing murmur, occurring generally in a single, but sometimes in many spots, commonly cutaneous or sub-cutaneous, but liable to grow in deep-seated parts, congenital or accidental, rarely exceeding a Seville orange in size, and often very small, traceable in rare cases to the influence of pressure or other external injury; sometimes of rapid, oftener of very slow progress; the true erectile tumour has a structure perfectly assimilable to that of cavernous tissue, and, like this, a structure not yet thoroughly unravelled. On section these growths (*fig.* 94) exhibit

Fig. 94.



Section of a true erectile growth. (*U. C. Mus.*)

on a coarse scale the interlaced columnar appearance of erectile tissue: the trabeculæ vary in thickness and density, and are provided with minute vessels; the hollow spaces between these are shallow or deep, narrow or broad, quadrangular or triangular, and communicate with each other. Microscopically the trabeculæ are found to be composed of fasciculated, cellular or fibrous (in very rare instances of intermingled elastic) fibrils, coated with tesselated epithelium, which consequently also lines the hollow interspaces. When these trabeculæ are in process of growth they contain fusiform cells.

Such Growths are never encysted, but they sometimes acquire a secondary capsule of condensed cellulo-fibrous membrane. It is said they are sometimes lobulated, a condition in which we have never seen them. They are rapidly regenerated if imperfectly removed. Particularly when connected with the skin, erectile structures may become the seat of cancerous formation.

Erectile Growths generally appear in superficial parts, the skin and subjacent cellular membrane; the mucous membrane of the anus (as a rare variety of pile); the gingival membrane (?); the tongue (Brown, in Lancet, 1833). Mr. Liston (Med. Chir. Trans. vol. xxvi.) describes an erectile tumour (Univ. Coll. Mus.) seated in the substance of the semi-tendinosus muscle; Andral (An. Path. i. p. 463) speaks as if the structure were not uncommon in the intestines,—but we have never seen it here; Lobstein describes it in the liver (?); Rayer (Maladies des Reins, t. iii. p. 612) in the kidney.

§ 5. MELANOMA.

Melanic cell-pigment, as described in a previous page (p. 116), may be deposited in the substance of various Adventitious Formations,—of Deposits (*e. g.* Tubercle), of Growths (*e. g.* Cancer), and of Pseudo-Tissues (*e. g.* Ossiform structure). Growths, more or less deeply tinged by its presence, have been distinguished as a special class of products under the title of Melanotic Tumours or Melanomata. Whether they have any real claim to such distinction will be best argued, when we have, in as few words as possible, glanced at the structural characters of Tumours of black colour.

These tumours are, in some instances, sarcomatous, in others composed mainly of enlarged vessels, in others cystomatous, in others fibrous,—the pigment being deposited between or within the convoluted fibres or vessels of the mass. But no growth contains melanic pigment so frequently as cancer. Studded in points through the cancerous masses, accumulated in lumps or equably infiltrated through their substance, the cell-pigment gives them a peculiar dark colour. This discolouration is by far the most common in the encephaloid species, and occurs most frequently in cancer of the eye, skin, and liver, but is not peculiar to any locality.*

Misled by the frequency of this discolouration of cancerous tumours, various writers have endeavoured to rank "Melanosis" generally as a cancerous disease. Lorinser, Laennec, Dupuytren, Alibert, Meckel, von Walther, and Cruveilhier, for instance, take this view of its nature; and more recently Müller has described "carcinoma melanodes" as one of his six *species* of cancer, holding as distinct and individualized a place in the class as Encephaloid or Scirrhus. The following reasons lead us to dissent altogether from these doctrines. (1.) That melanic pigment should in itself constitute cancer is an impossibility; it never even forms a stroma, as the cells continue permanently free. (2.) The stroma of many melanic tumours (as of those above referred to, fibrous, &c.) is perfectly distinct in its physical and chemical characters from all cancerous stromata. (3.) The microscopical characters of the pigment-cells and granules are the same in tumours of cancerous nature and in non-cancerous growths. (4.) Melanic tumours, when free from acknowledged cancerous elements, cause no special, local, or general symptoms. (5.) When melanic tumours give rise to the symptoms of cancerous disease, their solid stroma is found to be composed in whole or in part of encephaloid, scirrhus, or colloid. (6.) Neither the local nor general symptoms of cancers are

* The Univ. Coll. Museum contains a model of melanotic encephaloid of the vertebræ and spinal meninges.

modified by the presence of cell-pigment within them. (7.) "Melanotic tumours" are rarely solitary, it is urged by Cruveilhier; but this simply depends on the fact of encephaloid cancer being the growth most frequently impregnated with black pigment.

The stromata above referred to are the only kinds which we have ourselves seen or known of as elements of black coloured tumours in the human subject. But in the horse a species of melanic mass of different constitution is frequently met with; and may, for aught we know to the contrary, occur (if so, probably only in rare instances,) in the human subject.

These masses are of lobulated form, perfectly and deeply black in colour, sometimes attain great bulk, and feel remarkably elastic and spongy. Of the numerous specimens of the kind in University College Museum, an attempt has been made to inject one with a white material; a few spots of white colour in the substance of the tumour alone give evidence of the attempt; no trace of vascular arrangement is perceptible. A portion of the mass having been allowed to macerate in chlorine water for four days, the colour was rendered sufficiently faint for observation of the stroma. It consisted of delicate fibrils (gelatinizing with acetic acid) arranged parallel to each other, without the least appearance of meshes. The pigment-granules, which were not contained within cells, (at least, no cells were visible), lay upon the surface of the fibres in some places, so as on first sight to give an appearance of cross lines; in others they lay between the fibres. The conviction arises that this tumour may have been a hæmatoma; absolute proof is, we admit, yet wanting: if we are right, it would follow that the only doubtful kind of black tumour we have seen, possesses in reality, like all others, a stroma of ascertained nature, with black pigment added. And the observation lends indirect support to the view (still unestablished) of those who presume black pigment to be, under all circumstances, formed from the colouring matter of the blood.

Of Fat-Basis.

Growths of fat-basis agree in not being properly encysted, though they may occasionally acquire a secondary capsule from condensation of adjacent cellular membrane. The chief species are Lipoma, Steatoma, and Cholesteatoma.

§ 1. Lipoma.

Lipoma is a growth of softish consistence, somewhat elastic in form, generally disposed to be globular, though occasionally distinctly flattened; frequently lobulated, and furrowed on the surface; varying in size from very minute to vast dimensions, weighing from a few grains to ten, twenty, or (if records be true) forty pounds; ordinarily single, especially when of notable bulk:—two or three of the size of the clenched hand may, however, not unoften be seen together; and occasionally, when of very small size, considerable numbers coexist in the same individual.

Lipoma most commonly forms in the subcutaneous adipose texture (where it partakes of the characters of hypertrophy), but appears to be producible wherever cellular tissue exists. Müller has seen a lipoma between the corpora albicantia and optic nerve; Albers (*Pathologie*, b. ii. s. 189), found a lipoma of the size of a mushroom between the arachnoid and dura mater, on the level of the fourth lumbar vertebra; Andral (*Anat. Path.* ii. 412) describes one as large as a walnut, seated in the walls of the vena portæ. Growing between the peritoneum and abdominal wall, lipoma sometimes escapes by the abdominal rings, and constitutes the so-called "fatty hernia." In a fatal case of infiltrated cancer of the right lung, which lately occurred in our wards (Univ. Coll. Hosp.) a lipomatous mass had formed in the pleura of the affected side.

Lipoma on section, and even externally, presents the appearance and possesses the physico-chemical properties of common adipose tissue. The fatty elements, (margarin and olein) are removable with boiling æther. Microscopically the fat is found to be contained in cells, of the natural size, aggregated in parcels amid and upon the fibres of a delicate cellular tissue; the dimensions of the mass have no influence on its intimate constitution. The cells commonly of rounded shape, become much more rarely polyedral from lateral pressure, and are for the most part non-nucleated.

Their contained fat is fluid at the temperature of the body: when cool, separation of the olein and margarin takes place (as shown by Messrs. Todd and Bowman in the case of natural fat) and star-like groups of crystals of the latter form in the interior of the cell. We have occasionally seen free oil globules in lipoma, but whether arising from accidental rupture of containing cells or not, we cannot determine. The vessels of lipoma are of small size, and ramify in its stroma.

A delicate laminar cellular membrane invests the majority of lipomata: infiltration of texture is never effected by these growths. Their cellular investment may become fibrous, giving them a pseudo-encysted character. Pedunculation (single or multiple) is not uncommon; the peduncle sometimes stretching away to some distance from the main part of the growth; from the front of the sternum, for instance, deeply into the mediastinum.

The natural course of lipomata is to increase almost indefinitely in bulk, without giving rise to any other inconvenience than that arising from their size, weight, and position. The surrounding skin bears without ill results an extraordinary amount of distension; though eventually attenuation, low inflammation and gangrene have sometimes ensued. Lipomata are susceptible of inflammatory softening, (a rare occurrence however) leading to breaking down of their substance; the physical, and probably chemical qualities, of the fat change materially. Growths thus altered have

"become cancerous," in the erroneous language of their describers; we have never seen or read of a satisfactory example of cancerous formation, from a basis of lipoma. Fibrous thickening of the cellular septa of the growth is not uncommon; but a true fibroma is never evolved from a lipomatous tumour. Absorption of the fat may be effected by artificial pressure; the residual cellulo-fibrous structure forms a more or less dense mass.

Lipoma with excess of cellulo-fibrous stroma, much firmer than the simple variety, and more frequently invested by a pseudo-cyst, has been described under the names of Adipose Sarcoma, and Lipoma Mixture.

Lipoma has sometimes a semi-transparent almost gelatiniform look, the cause of which is not clear.

Müller proposes the title of lipoma arborescens for certain rare adipose formations, found in the joints. They originate behind the free part of the synovial membrane, protrude into the joint, and form tufts, nodulous at the ends. They are said to be most common in the knee-joint. The pleural lipoma, just referred to as having occurred in our own practice, might be accredited to this variety.

§ 2. STEATOMA.

There is a variety of fatty growth of greater density and solidity than lipoma, close in grain, inelastic, opaque, having the aspect of suet or sometimes of putty, wholly unlike natural adipose tissue. Such tumours, to which the name of steatoma is given, are composed of fat, soluble in boiling alcohol, non-vesicular, granular, and amorphous, and aggregated into masses without the intervention of cellular tissue. These accumulations sometimes acquire great bulk; we have seen them in the mesentery, testicle, and mediastinum.

§ 3. CHOLESTEATOMA.

See Cholesteric Fats (p. 94).

Of Gelatin Basis.

§ 1. FIBROMA.

Fibrous Growths appear naturally to affect the spherical form: they may, however, be accidentally flattened (as in the walls of the uterus, during the advance of pregnancy, Univ. Coll. Mus.); pedunculated (see p. 122) under the mucous membrane of the nose and uterus; or nodulated from having two or more centres of development. They may be smaller than a pea (in the dura-mater for instance); or, especially when developed under the peritoneal coat of the uterus, exceed the head of an adult in size: tumours of this kind have been known to weigh 25, 30, 35, and 39 pounds. Their external surface is naturally smooth and even; loose filaments of cellulo-vascular tissue form their common material of union with adjoining textures; in some cases the connection is rendered unusually intimate by exudation-matter. (See p. 125.)

On section the colour of these growths is generally found to be greyish-white,—the greyish colour being that of the intrastromal matter, the white (which may be dull or glistening) that of the stromal. Less commonly fibroma has a reddish hue. The consistence of the mass varies with its colour: the greater the whiteness, the greater the density, specific gravity and tenacity of the tumour; the reddish coloured growth is comparatively soft and yielding.

The constituents of fibrous tumours visible with the naked eye, are white bands; a material interposed between them of darker colour, less opaque, less dense, and less manifestly fibrous; and, in comparatively rare cases, vessels,—congregated in the main towards the periphery of the mass. The arrangement of the white bands and of the enclosed darker substance is peculiar: the bands follow an irregularly curvilinear direction; the loculi hence affect the spheroidal or oval shape. This character helps to distinguish fibroma from scirrhus with great excess of fibrous stroma; in such scirrhi the fibres always exhibit a tendency to rectilinear arrangement. By firm pressure a transparent, pale straw coloured (never lactescent), and glutinous fluid may be forced from a fibrous tumour: its quantity is very small, and it may be infiltrated through the growth or accumulated in spots.

Microscopically these growths are found to consist of fasciculated and intertwined fibres, less undulating in direction and less clear in outline than those of natural fibrous tissue, arranged parallel to each other, and studded or not with minute inequalities, produced by the still remaining nuclei of original cells. In the soft fibrous tumour this filamentous element is the same in character as in the hard; but it is less abundant, less closely set, and scarcely fasciculated: in this variety, too, it is more common than in the hard, to find cells with granular contents, some of them assuming the fusiform shape. We have occasionally seen fat-granules in these tumours; but fat is never one of their predominant elements.

When submitted to ebullition, the entire mass of a fibrous growth is converted into a jelly (glutin), with the exception of a very minute quantity of protein substance, derived, probably, from associated blood: the walls of the few cells, such tumours contain, are insufficient to account even for that minute quantity. Their saline constituents are, in various proportions, those of the blood. Valentin attempts to show that fibrous tumours of the uterus are sometimes composed of fibrin: doubtless, as we have already explained (p. 126) hæmatomata of the uterus occur, and may undergo evolution into fibrous tumours: but we altogether discredit the alleged fact, that tumours exhibiting the microscopical constitution of fibroma, are ever of protein-basis.

The nature of fibroma leads it simply to enlarge, without change in, or around, itself. Some alterations of texture are so common,

however, (the so-called cartilaginification and ossification) as to have passed for phases of evolution of fibroma; others (congestion, inflammation, serous infiltration, hæmorrhage, deposit of melanic matter, precipitation of fat, great development of vessels, and cancerous formation,) are, on all hands, confessedly morbid.

Patches, more or less extensive, and having the outward appearance of cartilage, are of common occurrence in fibrous tumours. The period at which this change occurs is indeterminate; nor has the size of the growth any appreciable influence upon it. We have examined some specimens of this kind without detecting any cartilage corpuscles, and incline to regard the outward change as simply signifying an increase of density and closeness of deposition of fibres.

Nor is the alleged "ossification" of these tumours, according to our observation, more real. We have not succeeded in detecting in the ossified-looking parts either the corpuscle or the laminated structure of bone, but simply saline particles or granules closely or loosely set in the organic basis of the tumour: actual ossification has, however, sometimes been seen. This saline precipitation commences indifferently in any part of the mass, and commonly shows itself in several points simultaneously, these being usually seated near the centre; it is far from unusual, however, to find most accumulation at the periphery, and not a few cases have been mentioned by Meckel, Louis, and others, in which the central parts, still fibrous, have been found encased in an earthy shell of variable thickness. The density of the calcareous matter (grey or yellowish in colour) varies greatly. If it be most common to find this substance friable and porous, in other cases, the saline substance is extremely hard and dense, resembling marble or eburnated bone. From Professor Daniell's analysis of a large tumour, described by Mr. Arnott (Med. Chir. Trans. xxiii. p. 202), we may infer the great extent to which the animal constituents may be replaced by inorganic salts, as also the nature of these: here were found, animal matter, *including water* and ammoniacal salts, 35; phosphate of lime, with a small quantity of phosphate of magnesia, 56; carbonate of lime, 5; alkaline sulphates, phosphates, and muriates, 4=100. The extent of the growth converted into calcareous matter varies greatly. Bayle refers to a tumour larger than a new-born infant's head, containing ten points of "ossification,"—the larger scarcely the size of a pea, the smaller not bigger than a grain of wheat: Mr. Arnott's case exemplifies the opposite extreme of almost total conversion into saline substance. When either converted altogether into earthy matter, or provided with an earthy crust of variable thickness, these bodies have been described as "calculi." Occurring most frequently in the uterus, these concretions of fibrous origin have also been observed in the cranium by Cruveilhier (Rev. Méd. Sept. 1833), by Krull and others. We have seen one as large as a walnut, which had been connected with the integuments of the face, in the possession of Mr. Liston.

The period at which calcareous deposition commences is altogether accidental. The size of growths has no influence upon it: the largest tumour we ever met with contained not a single earthy particle, visible with the naked eye; while it is common to find very small growths partially calcareous, and small and large tumours in the same uterus may present this change to an equal amount. It has even been maintained by Sebastian, that ossiform deposit is more common in small than large tumours; but although this idea may be rendered probable *à priori* by the consideration that the occurrence of this change would prevent further enlargement of the proper fibrous structure, yet we doubt strongly its being supported by facts. With the progress of saline precipitation (obviously so when the earthy changes occur on the peripheric surface, less distinctly and rapidly, though not less really, when they arise in the central parts) the connection of these growths with surrounding tissues, becomes less and less intimate; the vessels undergo obliteration, and a few filamentous shreds may alone keep up the union, until eventually the calcareous mass ceases to have structural connection with the organs. This condition is in some cases the prelude to its expulsion from the body. The saline matter sometimes appears to act as an irritant on the adjoining fibrous structure, and induce local exudation, suppurative or otherwise; probably this is the state referred to by Bayle, as "caries" of the alleged osseous structure of a fibroma.

Fibrous tumours of the reddish variety, soft, vascular, and of loose texture, are subject to internal congestion, which when these growths are situated in certain situations, as for example, under the mucous membrane of the uterus, may, aided by expulsive efforts of that organ, lead to rupture of the superficial layers of the growth, and terminate in external hæmorrhage. According to Madame Boivin, such tumours may be regarded to a certain extent as of erectile nature, inasmuch as they admit of becoming hard and tumid with blood at certain periods, especially the catamenial.

Hæmorrhage into the substance of the growth is a condition occasionally observed. Andral has noticed it, and we have seen a tumour containing a clot of considerable size.

Numerous small cavities are occasionally observed in these masses filled with red, and manifestly bloody, serosity; doubtless blood in an altered condition. These accumulations saturate and disintegrate eventually much of the solid substance.

Like all vascular structures, these growths are occasionally seized with inflammation — the hard variety much less frequently than the soft. This occurrence may be announced by severe local and general symptoms, increased by the participation of the surrounding tissues. The products of inflammation exuded into the substance soften and disintegrate it; pus of

pure character is rarely observed however. The tendency to inflammation is extremely slight, *inherently*, in these formations; when it occurs, it arises as a *secondary* consequence of their mechanical action on surrounding parts. This action produces various derangements of function of those parts, which are followed in them by irritative action, eventually spreading to the adventitious mass. The proof is, that growths so seated as not to lead to irritation of adjoining textures (sub-peritoneal pedunculated uterine tumours, for example) never, so far as our own observation and all recorded experience goes, become the seat of inflammation. We do not, however, mean to deny that in tumours of soft texture and abundantly vascular, an *intrinsic* process of inflammation may not possibly arise. Sphacelus may be the result of the former kind of inflammation; but this change, according to our observation, very rarely occurs with its *ordinary* anatomical characters.

Melanic colouring matter is sometimes deposited in abundance in these growths. Dr. Carswell (Elementary Forms of Dis. Melanoma, pl. 1. *fig*. iv.) has figured a very beautiful and characteristic specimen of this kind.

The softer species of fibrous mass has in the uterus been sometimes found to contain steatomatous matter and hair.

Krull has given a rough sketch of a uterine fibrous tumour, the central part of which contained vessels, some of them capable of admitting a pen, and said to present somewhat the characters of "erectile tissue"—a term very vaguely used.

Different notions have been held as to the possibility of fibrous tumours "becoming cancerous." The difficulty in deciding this question has arisen from the total want of definite meaning in the minds of authors as to what constitutes "becoming cancerous." If the phrase be applied in the manner which seems the only rational and sound one, that is, *to parts, whether adventitious or not, in which the development of one or the other of three species of cancerous formation occurs*, the perplexity of the question vanishes at once. The growth of cancerous substance in fibrous tumours is, in truth, at the least, materially more rare than in any natural vascularized tissue. We have never ourselves seen a particle of true scirrhus, encephaloid or colloid, in the interior of a fibrous tumour *proper*. The assertion of Dupuytren and certain of his copyists, that fibrous tumours frequently become carcinomatous, is easily explained: they confound the fungative and intractable sores sometimes arising on the uterine surface and adjoining sub-mucous fibrous tumour, with cancerous disease—applying the term, with a vagueness subversive of all correctness in morbid anatomy and in pathology, to every sore resisting treatment and affecting the constitution by its discharge and irritative agency. As well might they call the fungating sore, produced in the tongue or cheek by a carious tooth, a cancer.

The total expulsion of fibrous tumours from the body, is a phenomenon of less uncommon occurrence, than is usually supposed. It is effected while the mass possesses its original fibrous constitution, or after its conversion into earthy matter: the process in the latter case is much simpler than in the former, as the organic connections of the mass have been gradually destroyed in the manner already referred to; it is likewise of much more frequent occurrence. While yet fibrous, the growth may be expelled as a single mass or piecemeal; more rarely in the former way. The conditions necessary for its accomplishment are, that it should be separated from its connections, and, this once effected, that it should be so seated as to drop from the body spontaneously, or be under the influence of some expelling force. In the case of the uterus, the expulsive efforts of the organ lead to the removal of the masses (especially if seated under the mucous membrane) at a much earlier period, than their mere anatomical state would lead us to expect. The museum of University College contains a portion of fibrous tumour, expelled from the uterus in this manner; submitted to microscopical examination, we found it composed of precisely the elements already described.

The constitution of these growths would lead us to expect their local reproduction, if partially removed. Observation confirms this view. Cruveilhier describes, from the practice of Dupuytren, a case of fibrous tumour growing from the interior of the body of the lower maxilla, in which reproduction took place twice after imperfect removal with the knife.

The simple tissues in which fibrous tumours are observed are: the cellular; the fibrous; rarely, if ever, the osseous properly so called; the nervous. The compound tissues and organs in which they are more or less frequently developed are:—the bones, in immediate connection with the endosteum, or more especially the periosteum; the submucous tissue of the pharynx, more rarely of the œsophagus, of the stomach and intestines; the subperitoneal tissue; the submucous tissue of the larynx, the nares, the frontal and sphenoid sinuses; the sub-pleural tissue; the arterial tissue; the ovaries; the Fallopian tubes; the uterus; the vagina; the mamma; the testicle; the dura mater in its subjacent cellular tissue; the nerves; the thyroid gland; the thymus gland. Of these various parts, the uterus, dura mater, ovary, and mamma suffer, especially the two former, with incomparably the greatest frequency. A single one, or several fibrous tumours may exist in the same body. Usually numerous, for example, when affecting the dura mater; they are commonly single in the bones. Their coexistence in several distinct organs is extremely rare.

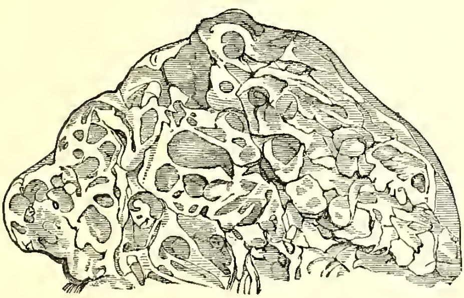
ENCHONDROMA.

Enchondroma (from εγχονδρος, *cartilaginous*,) is the name recently proposed by Müller for a species of cartilaginous growth, not unknown to previous observers, but by

many surgical writers confounded, under the erroneous name of "cartilaginous *exostosis*" (erroneous, if for no other reason, because the formation in question may spring from other tissues than bone), with products of essentially different character, and by some other authors described as colloid cancer.

When *uncut*, enchondroma exhibits itself as a tumour of moderate size and spheroidal non-lobulated shape, encased in cellular membrane, or (if it spring from bone) in periosteum, ossified or not. The *section* discovers a firmly gelatinous substance, rather pellucid, of very pale greyish or greenish yellow tint, set (without firm adhesion) in loculi inclined to spheroidal outline, varying in size, and having their walls formed of a dense dull white tissue (*fig.* 95). One of the rough marks

Fig. 95.



Section of Enchondroma. (After Müller.)

of distinction between this growth and colloid cancer consists in the mode of arrangement of the walls of the loculi: in the latter, when fully grown, the walls seem cut across sharply at right angles with their course; in the former it is extremely common to find the walls exhibiting flat and extensive surfaces to the eye, as though the loculi had been opened to a very small extent only.

The general mass is firm; when the investment is periosteal or bony, proportionably increased. The intra-locular matter is in itself soft, yet has a sharp fracture. Bony matter in its interior of course increases its consistence, and may be formed of: 1, the walls of the loculi converted into thin osseous plates, which give a crackling crispness to the mass; 2, particles of the spongy tissue of the original bone in which it has grown; 3, stalactiform osteophytes springing into its substance.

No appearance of vessels strikes the unassisted eye in these masses; but von Walther and Weber (Gräfe and Walther's Journ., b. xxiii. s. 351.) are said by Müller to have injected the walls of the loculi.

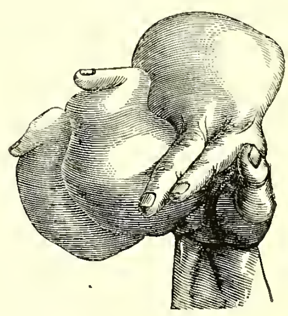
Microscopically examined, the fibrous portion of the growth is found to be composed of transparent interwoven fibres. The jelly-like part consists of cells several times larger than the red blood-corpuscle, generally speaking, containing only nuclei in their interior, but in some instances two or three sub-cells, each provided with its own nucleus. The nuclei, flattened, oval or circular, vary in diameter. The cells (except in excessively rare cases) are in close contact with each other, and no inter-cell substance discernible between them: the cartilaginous material does not advance beyond the embryonic stage. Such is Müller's description; but it is certain that tumours having the characters of enchondroma perfectly developed to the naked eye, and yielding gelatin, may be wholly deficient in cartilage corpuscles, and contain simple granulated cells in a fibrous stroma.

Spiculated bone corpuscles are sometimes scattered through the tumour.

From this account it would appear, that although the endogenous mode of growth of the cells occurs occasionally in this formation, it is neither uniform nor constant; their development proceeds more frequently from blastema lying outside such cells as are already evolved. The endogenous development was observed especially by Müller in an enchondroma of the parotid gland. Whether the inter-cell substance is generated by thickening of the walls of the cells, or by the hardening of a blastema unconnected, except in respect of proximity, with these, is matter of dispute. Enchondroma is essentially composed either of chondrin or of glutin; of the former in by far the greater number of cases; of the latter, in Müller's specimen connected with the parotid gland, and in another connected with the ileum, recently added to the University College Collection.

The bones are the favourite seat of this growth. Müller has collected thirty-six cases, in thirty-two of which those organs were affected: the *metacarpus and phalanges 25 times;* the tibia 3; the ileum 1; the cranium 1; the ribs 1. Of the four remaining tumours, 1 existed in the parotid; 1 in the mamma of a dog; 2 in the testicle. In its favourite seat — the metacarpus and phalanges — this disease produces singular distortion and irregular tuberousness of the hand (*fig.* 96).

Fig. 96.



Enchondroma, from model in Univ. Coll. Mus.

Enchondroma, springing from bone, is invested or not with a bony capsule. When it grows in the interior of a long bone, expansion, and not perforation of the shell, occurs; the cancellated structure first, and then the

cortical, undergo softening and rarefaction, and are gradually spread out into a globular sac. New bony matter is also thrown out, helping to complete the capsule, which is, even with this assistance, commonly imperfect. When developed in bones of very spongy texture, perforation may, according to Müller, occur, instead of expansion; we believe that, in at least some such cases, the growth originates in the sub-periosteal cellular membrane. In this latter variety the form is less regularly spheroidal than in the other; but the texture is the same in both.

The progress of enchondroma is slow; its effects fundamentally are purely mechanical. Adhesion of the skin only occurs as an accidental effect of inflammation: rupture of that membrane only from excessive distension; the resulting ulcer may discharge abundantly, and inflammation arise from this cause, as from external injuries, but not apparently from intrinsic spontaneous changes.

Enchondroma of the bones, like every other affection of those organs attended with enlargement, has been described under the names osteosarcoma, osteosteatoma, and spina ventosa — terms devoid of definite signification. Scarpa speaks of it as "malignant exostosis," a double misnomer—for its course differs essentially, as has been seen, from that of cancerous maladies, and it does not necessarily spring from bone.

Colloid cancer might possibly be confounded with enchondroma. We have already alluded to a rude mark of distinction between the two products; further, colloid cancer rarely (never so far as our experience goes) occurs in bone, the chosen site of enchondroma; the effects of the two products on adjoining tissues are essentially different — enchondroma never infiltrates structures, colloid frequently does; colloid never contains patches of bone, enchondroma does so commonly; colloid is of protein basis, enchondroma yields chondrin, or (rarely) glutin.

Certain sarcomata of the maxillæ have much outward resemblance to enchondroma; but they contain spherical cells with granules and fusiform corpuscles, and are besides of albuminous composition.

§ 3. OSTEOMA.

The arrangement of abnormal ossifications has puzzled more than one pathologist. Excluding exostosis and hyperostosis (mere local and general hypertrophies) we propose to examine here all varieties of bone-production *in unnatural sites*. We adopt this course, in order to avoid recurrence to the subject under the head of PSEUDO TISSUES, being aware that ossiform masses, having the generic attributes of Growths, ought alone to figure in the present place. Hypertrophy and new production of bone, as in the venereal node, are frequently associated; and adventitious bone (whether springing from a new cartilaginous matrix or not) is very rarely perfect microscopically, perhaps never so chemically: two fundamental propositions.

Adventitious bone forms (*a*) as an infiltration of natural tissues; (*b*) as the callus of fractured cartilage; (*c*) as an osteophyte; (*d*) as an ostema; (*e*) as an osteoid; (*f*) as an infiltration of new products.

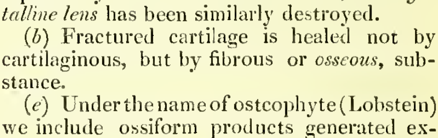
(*a*) *In the natural tissues.* Articular *cartilages* ossify in some situations with advance of life, as for instance, in the cranium; the material uniting eroded articular surfaces ossifies; ossification of the costal and laryngeal cartilages (perhaps more common in phthisis, in proportion to the age at death, than in other maladies) is affected by calcareous deposition in the cartilage cells and inter-cell substance, and by generation of new bone lacunæ. Cartilage morbidly ossified, as that naturally ossified, yields glutin and not chondrin. The anterior vertebral *ligament* is sometimes ossified in tubercular caries of the spine. We have seen the *tendons* of the legs infiltrated with ossiform substance. The fibrous capsules of the spleen and kidneys are sometimes thus affected, and *aponeuroses* and *fasciæ* are often, and the *elastic* ligamentum nuchæ, more rarely, in a similar predicament. — *Cellular membrane.* The *submucous* tissue of the gall-bladder; the *subserous* of the pleura (as a specimen before us proves); the *subretinal*; the *intra-muscular*; the parenchymatous (of the liver); are all the occasional seats of bone development. *Muscle* has disappeared and been replaced by bone in some rare cases; the *crystalline lens* has been similarly destroyed.

(*b*) Fractured cartilage is healed not by cartilaginous, but by fibrous or *osseous*, substance.

(*c*) Under the name of osteophyte (Lobstein) we include ossiform products generated externally to, but under the influence of, some one of the natural bones. Formed from extra-osseous exudation an osteophyte may be separated from its parent bone, without necessary injury of this (herein differing from true exostosis); and is produced independently of, or in connection with, other pre-existing new formations.

Osteophytes assume shapes singular and various, yet in some measure characteristic of their origin. Thus they are flat, and more or less broad in nodes; narrow, triangular, and semicircular in cephalhæmatoma; foliaceous, (*fig.* 97), stalactiform, cauliflower,

Fig. 97.



Foliaceous osteophyte of the clavicle; the foliæ (b) running at right angles with the axis of the bone (a). (U. C. Mus.)

(U. C. Mus.), or stellate, when plunging into soft growths; styloid when passing in front

of a vertebra destroyed by caries; sacciform, when investing a soft growth from bone; warty, when found about gouty joints; membraniform and lace-like in the cranium of pregnant women.

The flat osteophyte (sometimes separable from the subjacent bone) is best exemplified in nodes, though it forms under the influence of common periostitis or adjoining inflammation, as beautifully shown by the ribs of an old sufferer from empyema, preserved in the University College Museum. If a node be carefully examined, it will be found in part to consist of hypertrophy with rarefaction of the superficial stratum of the original bone; and in part of ossified subperiosteal exudation. The canaliculi in the latter run at right angles with the axis of the bone,— proving absolutely the existence of a separate centre of ossification: the fact is exemplified on a large scale, in *fig.* 97. And it is further illustrated by a portion of carious lower jaw-bone (now before us), separated from the face of a dipper of Congreve matches, labouring under the singular disease peculiar to workers with phosphorus. On the inner surface of the ramus of the bone (kindly lent to us by Mr. Quain, whose patient the man was *,) appears a flattish osteophyte, partly fibrillar, partly porous and pumice-stone like, of dark greyish colour, and easily separable at the edge from the maxillary surface: elsewhere are friable earthy-looking particles.

But the most singular of osteophytic productions is certainly that which forms in membraniform patches between the cranium and dura-mater of a certain (as yet unsettled) proportion of pregnant women. The natural history of this production (of which a beautiful specimen lies before us) has been unravelled with great sagacity by M. Ducrest.† Exudation matter soft, pulpy, and reddish, forms the matrix of the future osteophyte; it soon becomes sandy to the feel; subsequently hard particles of some size are felt, and these form eventually one, more or less perfectly, continuous plate. The frontal regions are its chosen seat, and M. Ducrest shows that its formation occurs symmetrically. Its thickness does not exceed a sixth of an inch, and is generally much less; the specimen before us (irregular thickness from point to point gives this a lace-like appearance) forms a coating for the entire base and upper arch of the skull; but its superfical extent is very rarely so considerable. When fresh it is of red colour; twice (in jaundiced women) M. Ducrest found it yellow. This production, which entails no symptoms, is more prone to appear in young than in more aged women.

(*d*) Osteoma. By osteoma we understand a growth composed of bone, and either (a) altogether free from, or (b) having but very slight, connection with any part of the skeleton. Tumours of the former kind (a) are of excessive rarity, and are perhaps only met with as results of bony infiltration of a pre-existing plastic mass, either of the serous cavities or of the parenchymata; it seems unnecessary to insist upon the greater frequency of calcification than of true ossification of such masses. Tumours of the latter kind (b) are best exemplified by growths from bone, generally termed pedunculated exostoses, in which the pedunele may be so small, and the body of the growth comparatively so large, that a centre of ossification distinct from the original bone appears to exist. Such productions are not very unfrequent about the phalanges of the toes; their texture is generally loose, but may be eburniform from density.

(*e*) *Osteoid.* — Under the names of osteoid or ossifying fungous tumour, Müller describes a growth of slow or rapid course, generally springing from the surface of bones, sometimes acquiring great bulk, composed of porous or close osseous texture, and of a greyish white, vascular, nodulated substance, of the consistence of fibro-cartilage, the latter lying in the interstices of the former. The softer substance furnishes neither glutin nor chondrin by boiling, and exhibits a dense fibrous rete under the microscope, containing a few nucleated cells in its meshes. The formation of osteoid growths seems dependent on a peculiar diathesis; they generally appear at first on one bone, but may eventually invade several bones and certain soft parts — the lungs, great vessels, &c. The removal of a primary growth by amputation does not prevent the development of others internally. Cruveilhier's osteochondrophyte (Anat. Path. livrais. 34), is a production of this class; this writer calls the soft part of the tumour cartilage, but gives no proof of its being so.

(*f*) Bone formation in the interior of new products (exclusive of osteophytes springing from some part of the skeleton) is very rare. We have never seen such bone in cancer or in fibroma; but there is sufficient evidence that it has, in some rare instances, been observed.

Of Undetermined Basis.

COLLOMA.

Perhaps the word Colloma will not be objected to as a *pro tempore* name for the gelatinous-looking matter, which is of common occurrence in the interior of cysts, and occurs less frequently, unprotected by such investment, in the limbs and elsewhere. Tremulous and soft, sometimes sufficiently so to be almost poured from the part containing it; generally amorphous, sometimes fibrillar, *never stromal*, as seen with the naked eye, this substance appears transparent and amorphous under the microscope. It contains no interstitial vessels.

This substance yields no gelatin by boiling; nor is it composed of albumen (though it may furnish traces of this principle): it is therefore chemically different from the jelly-

* This man is now in excellent health, and manages to masticate with the aid of a fibrous representative of his lost jaw.

† Mémoires de la Soc. Méd. d'Observation de Paris, t. ii.

like matter of true gelatin-yielding growths, and of colloid cancer; from both which it also completely differs in structural characters.

Müller figures under the title of Collonema a soft gelatiniform tumour of the brain (seen also in the breast), composed of grey-coloured cells, a few fibres and vessels, and acicular eystals, soluble in boiling æther. The reactions of the growth in the brain most closely corresponded to those of ptyalin (?); that in the breast contained a minute quantity of casein.

SUB-ORDER II. — INFILTRATING GROWTHS.

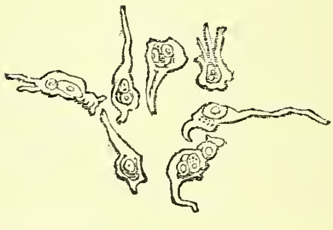
CANCER OR CARCINOMA.*

In this sub-order we place as a genus the product Carcinoma, containing three species — encephaloid or soft, scirrhus or hard, and colloid or jelly-like, Carcinoma. "The union of these three morbid structures," as we have elsewhere observed, "into a distinct genus, is, in truth, not a mere nosological artifice: it is manifest that the formations, to which I thus apply the generic term cancer, possess characters entitling them to be grouped together, and separated from all others to the generation of which the organism is exposed. They agree *anatomically*, for they are all composed of elements forming a combination without its counterpart, either in other adventitious products or in the natural structures: they agree *chemically*, for they are all distinguished by the vast predominance of protein-compounds in their fabric; they agree *physiologically*, for they all possess in themselves the power of growth and of extending by infiltrating surrounding tissues, and so producing an appearance of assimilating to their proper substance the most heterogeneous materials,—an inherent tendency to destruction, and the faculty of local reproduction; they agree *pathologically*, for they all tend to affect simultaneously or consecutively various organs in the body, and produce that depraved state of the constitution known as the cancerous cachexia." But, on the other hand, these three structures are not one and the same *ab initio*, as is contended by some writers: each may be developed in the others; but encephaloid stands apart from its co-species by containing true cancer-elements in greatest abundance, and in the purest and most unadulterated form, — scirrhus derives speciality from its lavish supply of fibre,— colloid from an unimitated condition of gelatinousness. And, again, we maintain that the three products are not mere varieties, — they are actual species, because each of them, as just stated, has its own constant structural attribute.*

The ultimate elements met with in cancerous Growths are of three kinds,— essential, almost essential, and merely contingent.

(*a*) The essential elements are granules, cells, fibres, blastema, and vessels. *Granules* exist to various amounts in all varieties of cancer; average $\frac{1}{10000}$ of an inch in diameter, and either float free, or are seated within cells, or upon or between fibres. They are composed of a protein-substance, or of fat. The *cells* of cancer are spherical or imperfectly caudate. The spherical variety (sometimes oval or discoid) measuring, on an average, about $\frac{1}{1900}$ of an inch, may reach only the $\frac{1}{3500}$ of an inch, or, on the other hand, attain the diameter of $\frac{1}{900}$ of an inch, in diameter. The cells of small dimensions are particularly to be seen in scirrhus, where endogenous cell-production is rare; the bulky elass in colloid cancer, where they stand in the relation of parent-cells to a contained progeny of sub-cells. The thickness and transparency of the cell-wall vary; it is sometimes collapsed, sometimes full and tense; almost always colourless. The caudate variety of cell exhibits itself under two forms: first, that of an irregularly branched corpuscle, having in its interior a spherical cell, itself provided in turn with a nucleus or even containing nucleated sub-cells (*fig.* 98); secondly, that of the

Fig. 98.



Caudate cells (from encephaloid of the stomach), containing nucleated sub-cells. Length $\frac{1}{1000}$th to $\frac{1}{500}$th of an inch; width $\frac{1}{2500}$th to $\frac{1}{2000}$th inch. *Magnified* 400 *diams.* (*From Author's work on Cancer.*)

fusiform cell seen in sarcomatous Growths (see *fig.* 93, p. 127), and in exudation-matter undergoing development into pseudo-fibrous tissue. The first form of caudate cell is scattered in an isolated manner through the growth; the second may accumulate in fasciculated bundles, so as to simulate fibre. (See *fig.* 93, p. 127.) The contents of cells are a certain fluid, granules, nuclei, and sub-cells. Granules are abundant in the cells, more especially, of scirrhus. The nucleus of the cancer-cell is an

* As the present article has already reached a considerable length, and as we have very fully treated the subject of Cancer in another work, we shall confine ourselves here to a statement of some few facts bearing on the morbid anatomy of cancerous growths. We are the more disposed to venture upon this course, as nothing which has, to our knowledge, been made public since the appearance of the work in question, requires us to add to, or take from, any of the doctrines or expositions of fact it contains.

* The division into species is objected to as deficient in the perfection of zoological classifications. Who, except the artificer of the objection, could have imagined, that even an attempt was made to reach such perfection?

oval, flattened, parietal, comparatively opaque body, generally speaking of large size in proportion to its cell, and often exhibiting a furrow on its surface or indentation at its edge, (see *fig.* 6, *a.* of the author's work on Cancer), a condition preparatory to its splitting into two. Each nucleus is supplied with one, two, or, it may be, so many as four minute bright corpuscles — its nucleoli, which in turn probably contain sub-nucleoli. When a nucleus splits in the manner referred to, the resultant bodies may be fairly regarded as sub-cells,— they are manifestly hollow, granular, and themselves nucleated.* The diameter of the nucleus varies between the $\frac{1}{3500}$ and $\frac{1}{3000}$ of an inch, averaging $\frac{1}{3200}$ of an inch. *Fibres* exist under different forms in cancer. First, delicate, non-adherent broken fibrils occur in most specimens. Secondly, true fibrous tissue occurs in the loculus-walls of colloid, and forms the stroma of scirrhus. Thirdly, excessively delicate, almost transparent fibres exist in a special variety of soft cancer, the fasciculate. The unevolved *blastema* of a cancerous growth varies in quantity, and is perfectly fluid, or somewhat viscid. Particles of amorphous substance, gelatinising under acetic acid, may sometimes be found associated with it. The *vessels* of cancer are either those of the natural structure affected, or are actual new formations; they are exceedingly abundant or very few in number. The veins are frequently plugged with cancerous matter, so as to prevent them from being injected.

(*b*) We are disposed to regard fat as an almost essential element of cancer, (or rather as a substance tending to be produced whereever cancer exists,) so constant is its appearance, either in the oil-globule or the granule forms (adipose-cells, if present, come from the implicated natural tissue). When fat abounds in these growths, it appears to have the effect of altering the form of the cancer-cell, and certainly modifies the naked-eye characters of the tumour.

(*c*) The contingent materials met with in carcinoma are saline particles, crystalline (Op. cit. *fig.* 11) or amorphous and calcareous,—the latter in very rare instances accumulating sufficiently to become perceptible to the naked eye (calcification ;) crystals of cholesterin and patches of cholesteatoma; perhaps in very rare instances tuberculous deposit† ; melanic matter ; blood fluid, clotted, in the state of fibrinous hæmatoma, or of "apoplectic cyst ;" exudation-matter with its spherical and fusiform cell; pus ; and (on ulcerated surfaces) certain epizoa and epiphyta. The pseudo-tissues which may be actually *formed within* the area of cancer (any natural texture may be *invested* by cancer) are epithelium, the cellular, serous, fibrous, and elastic tissues and blood vessel. Spiculated osteophytes, preceded (sometimes at least) by sprouting cartilage, not unfrequently plunge into the substance of cancerous growths from some connected part of the skeleton : an isolated generation of true bony structure, in a nidus of blood-blastema, within a cancerous tumour, seems a possible occurrence (it is at the least, a singularly rare one) ; but the possibility of such generation in actual cancer-substance seems only admissible on the principle that the freaks of nature are boundless in their variety.

Built up of materials, such as these, are all cancers. Encephaloid, soft, brain-like, rapid in its evolution, attaining great bulk, highly vascular, prone to bleed and fungate, is microscopically distinguished by its deficiency in fibrous stroma and the abundance of its fluid blastema and its cells. Scirrhus, hard, tough, slow in growth, and reaching moderate dimensions only, poor in vessels, rich in fibre, differs microscopically from its co-species in its abundance of fibrous stroma and the comparative fewness of its cells, which mainly grow on the exogenous plan. Colloid, crisp in its mass, soft in the jelly-like ingredient that fills its loculi (models of the spherical loculus), but slightly vascular and semi-transparent, stands apart microscopically from encephaloid in the well-marked fibrousness of its loculus-walls, from scirrhus in the abundance of its endogenously-growing cells, from both in the abundance of its viscid jelly-like element.

The chemistry of cancer is yet in its infancy. Its organic basis is essentially protein, — its saline constituents those of the blood. That there is a difference in chemical nature between colloid and the other species, seems plain from the fact that the former retains, the latter lose, their transparency in alcohol : Müller conjectures that colloid contains a compound analogous to ptyalin. Microchemically the cells of cancer are insoluble in cold and boiling water, and are not seriously affected (in respect of solution) by acetic acid : the cell-wall has been said to disappear under the influence of the diluted acid ; but it is simply rendered pale, and may be restored by the ioduretted solution of iodide of potassium, which at the same time greatly deepens the colour of the nucleus.

We have already said (p. 124) that a constant and unfailing microscopical characteristic of cancer has hitherto been vainly sought for ; the following propositions will serve as a commentary on, and, in some sort, a justification of, the statement. (1.) Parent cells, containing within them sub-cells having darker nuclei, and these, in turn, bright nucleoli, are strongly characteristic of cancer : but such cells are rare in, and may be altogether absent from, scirrhus ; encephaloid in some phases of its growth may also be without them. (2.) The shapelessly-caudate cell (see *fig.* 98) seems significant of cancer ; but it may be absent from encephaloid, and it is excessively rare in scirrhus or colloid. (3.) A

* Where a system of cell-encasement, such as that observed in cancer prevails, it is plain, difficulty must be felt in assigning with precision the titles of sub-cell, nucleus, and nucleolus.

† We have never *seen* this, and we know that the naked-eye aspect of tubercle may be simulated in an encephaloid growth by excessive accumulation of fat.

tumour may present to the naked eye the characters of encephaloid, be the seat of interstitial hæmorrhage, affect the communicating lymphatic glands, run in all respects the course of cancer, and nevertheless contain no cells but such as are undistinguishable, in the present state of knowledge, from common exudation-cells. (4.) Nay more, while a primary "malignant" tumour contains these cells alone, the lymphatic glands secondarily affected may contain compound nucleated cells, spherical and shapelessly-caudate.* (5.) The granular and imperfectly nucleated cell of scirrhus is valueless as an evidence of cancer. (6.) The true fusiform cell (*fig.* 93) is an adventitious formation when it occurs in cancer, and has no diagnostic signification. (7.) The association of fibre and cell-structure, which will distinguish scirrhus from fibrous tumour, may be totally wanting in encephaloid, and exists in sarcoma and enchondroma. (8.) If fat be associated in large quantity with fibre and cell-structure, the certainty that cancer is present becomes great, but not absolute.

The property of infiltration, which serves well, as we have shown (p. 125), to distinguish cancer *from other growths* nosologically, fails practically in the distinction of tumours generally, because a true cancer *is not necessarily* infiltrated, and because tubercle and exudation-matter *may be* infiltrated. In ultimate analysis the *single* character least likely to deceive is this: if a tumour be cancerous, it will yield on pressure an opaque, whitish (milky or creamy-looking) albuminous fluid †; if it be not cancerous, it will not yield a fluid of these qualities.

Order III. — Pseudo-Tissues.

The blastema from which Pseudo-Tissues are evolved is commonly known as coagulable lymph, itself nothing more than liquor sanguinis slightly modified in nature, and in the proportion of its elements (the modification consisting in excess of fibrin,—it comes from hyperinotic blood,—and in the presence of gelatin, Mulder), and like it composed of water, fibrin, albumen, fat and salts. Produced by exudation from the vessels, homogeneous and amorphous, this fluid soon becomes the seat of cell-formation, the cell being that already described as the compound granule corpuscle. The fibrin it contains coagulates into patches or flakes of yellowish grey colour, semi-transparent, amorphous to the naked eye, but fibrillar (in parallel fasciculated rows) under the microscope, the cells (and abundant granules) appearing set in or upon the fibrils. Hæmatin, or entire blood-disks may appear, and pus corpuscles be produced, amid these coagula.

Now the issue of this exudation-matter (which seems regulated rather by the constitutional state than by its own nature) may be of two kinds. Either a permanent material sui generis (which, for want of a better name, we will call *Induration-matter*) is produced; or a structure resembling some one or other of the natural adult tissues is evolved. The former result signifies a lower plastic power than the latter: the *necessity* of active congestion for the production of either is more than doubtful.

Induration-matter.

Coagulable lymph, destined to remain in the condition of induration-matter, becomes more and more opaque and solid, and acquires an imperfect fibrous character (as Mr. Gulliver first showed) from simple condensation of the original fibrillated fibrin, and independently of cell-formation. The fibres become thicker, and run more flexuously, as the consistence increases,—a change probably caused by contraction from removal of water.

The properties of induration-matter vary greatly. Of greyish, yellowish, or white colour; opaque; fragile and cheesy in consistence, or firm as fibro-cartilage; of trifling, or of extreme tenacity; rarely crisp, and generally distinctly tough; commonly elastic; in its firmest condition creaking on incision; occurring in the forms of membranous layers, more or less perfect sacs, nodules, patches (plane, puckered, cupulated, or convex), points, granules, wart-like bodies, or altogether amorphous; essentially of protein-basis, yet yielding gelatin in a certain proportion, prone to contain fat (granular or cholesteric), and often becoming the seat of saline (ossiform) deposits; induration-matter is perfectly similar to none of the natural textures. As it hardens, its texture densely and closely set, often acquires a chondroid appearance without containing a particle of true cartilage; it is imperfectly (or not at all) vascular. Microscopically it is found to be unprovided with prolific cells; nor are the few cells it may contain, nucleated as a general fact. It is rendered pale by acetic acid.

Induration-matter is endowed to a remarkable degree with the property of slow contraction,—a property which renders its presence most beneficial or most baneful. It is this property, on the one hand, which in the process of cicatrisation by granulation, reduces within reasonable limits the surface of the largest wounds; while on the other, it may cause painful deformity, as in the instance of burns, or actually cause death, as in the instance of healing intestinal ulcers.*

Presenting itself wherever vessels exist, and entering non-vascular textures by imbibition;

* Mr. Ellis has recently ascertained this fact in examining a testicle, and communicating lymphatic glands.

† We have found this the fact even with cancers of excessive transparency and wateriness of look. (See Op. cit. p. 17.) Colloid cancer is comparatively poor in this kind of fluid; but fortunately its other characters unfailingly identify it.

* The *cure* of ulcers of the small intestine in continued fever and in phthisis, and of the large bowel in chronic inflammation, has more than once proved the cause of fatal stricture.

co-existing with all varieties of textural change, and exercising important influences on local nutrition, induration-matter would require a volume for its full description. We must content ourselves with an enumeration of some of the principal sites in which it occurs. Induration-matter forms: (A.) *On membranous surfaces*, where it is known under the names of pseudo-membrane, matter of adhesions, &c. Of the serous class the pleura is by far its most common seat; next follows the pericardium; then the peritonæum; then appear the tunica vaginalis and synovial membranes; and longo intervallo the arachnoid.* Among mucous membranes it appears on the respiration-surface in croup, plastic bronchitis, and pneumonia (in all which situations it is not distantly allied to diphtheritic deposit), and on the intestinal surface as in dysentery. It appears on the endocardial and valvular surfaces in the warty and granular forms; in the arteries and veins in the patch-like shape. The so-called glands of Pacchioni illustrate its occurrence on fibrous surfaces. (B.) *Free in cavities.* So it has been occasionally found forming rounded masses in the peritonæal and pleural sacs; the so-called "loose cartilages" in joints are in the great majority of instances composed of induration-matter; so too are those small melon-seed-like bodies, producing double saccular distension at the wrist-joint.† (C.) *In the cellular membrane.* The sub-cutaneous, (less frequently than the sub-mucous, and still less than the sub-serous) cellular membrane, becomes infiltrated with this material; in parenchymatous cellular tissue it is singularly common. In addition to the ordinary cases of its occurrence in the latter, as a result of simple inflammation, it constitutes in great part the substance of the morbid element infiltrating the kidney in certain cases of renal disease attended with persistent albuminuria, urine of low speeific gravity, anasarca, &c.; infiltrating the capsule of Glisson, it plays a notable (but not the whole) part in hepatic cirrhosis; and infiltrating the substanee of the lung (especially in certain cases of empyema), it converts that organ more or less completely into a chondroid mass. Seated in the intra-serous fibro-cellular tissue of the cardiac valves and chordæ tendineæ (where it is associated sometimes with atheroma) its contractile force produces the puckerings and shortenings so frequently observed. (D.) *As imperfect cicatrix.* Wherever a solution of continuity occurs, the cicatrix *may* be formed of this substance; take the instance of false joints: in some situations cicatrix seems always to be thus constituted, of which more in the next section. (E.) *On new surfaces.* Induration-matter may form on wounded, burned, and ulcerated surfaces; and supply a sac more or less perfect round the cavity caused by abscess, tuberculous softening, and fistulæ.

* We have never seen arachnoid adhesions, unless in connection with tumour of the brain or meninges. Is idiopathic arachnitis always fatal?

† We have found these bodies hollow centrally; their capsule is composed of amorphous albuminous matter with a little fat, and occasionally calcareous particles.

SUB-ORDER II.

SIMULATING THE NATURAL TISSUES.

When endowed with higher plastic quality exudation does not remain as induration-matter, but becomes the matrix from which a structure more or less closely imitative of some natural tissue is evolved. This imitation is never perfect, at once physically, chemically, and physiologically,—at least in respect of the higher orders of texture. A pseudo-tissue thus generated may be wholly adventitious; or partially so, as when designed for the reparation of lost parts.

EXTRA-VASCULAR TISSUES.

Epithelium.— On cicatrising and on fistulous surfaces, on the inner wall, or amid the contents, of cysts, as a coating for hæmatomata, and as a lining for new vessels, tessellated epithelium occurs as a purely adventitious product. The retained and accumulating epidermis forming corns and callosities, or that thrown off in excess from the skin in pitiriasis, or from the genito-urinary mucous surface in various states of disease, or from the intestinal surface in cholera, &c., can only be viewed as products of supersecretion. Hypertrophy of the papillæ of the skin, with excess of epidermal formation (Univ. Coll. Mus.), a state prone to give rise to obstinate ulceration, cannot fairly be considered under the present head. Perhaps the epithelium accumulated in cutaneous sacs produced by dilatation and occlusion of sebaceous follicles may be considered adventitious. So likewise are those productions, elongated or flat, known as "horns," and which are essentially composed of epidermis. Commonly springing from a dilated and diseased sebaceous follicle, and mixed abundantly with fat, slightly with saline matter, the basis of the future "horn" is at first soft, subsequently becomes inspissated and hard, when its increasing dimensions, earrying it beyond the limits of the follicle, place it under the influence of the atmosphere. Layer upon layer of epidermis eontinues to accumulate at the surface of the follicle, and eventually a conical mass, some inches in length, may be the result. Horny-looking productions sometimes form on ulcerated surfaces, simple or cancerous.

Pseudo-tumours, composed essentially of epithelium, and susceptible of vascularization, form, it is affirmed, on some mucous surfaces, —the uterine for instance. We have not met with productions of this kind.

Nail. — (See Tooth, p. 143.)

Cartilage.— Adventitious eartilage, at one time believed to take rank among the most common, is now known to be one of the rarest of new formations: the microscope has certainly dispelled a cloud of error on this subject, by simply showing that cartilaginous-looking products are not necessarily

cartilaginous. Such products are most commonly composed of dense fibrous substance, or induration-matter,— as in the instance of so called loose cartilages of joints.*

Adventitious cartilage is either of the embryonic or adult type: the former has already been described under the name of enchondroma. Cartilage of adult type, certainly, sometimes forms the matrix in which adventitious bone originates; this we have seen beautifully exemplified in spicular osteophytes. Analogy would lead to the admission that a cartilaginous stage should always precede bone-production; yet not only is proof of the constancy of this stage wanting, but we have looked in vain for its traces in many specimens of adventitious bone. In a very few preparations of that rare variety of false-joint in which a pseudo-synovial membrane is produced, the bony surfaces (whether from fracture or dislocation) have exhibited a cartilaginous look in patch-work; but we have not had an opportunity of submitting such a specimen to microscopical examination. Of the appearance of cartilage in various Growths enough has already been said.

Nor is the production of cartilage for reparative purposes more easy. A fractured cartilage unites by dense fibrous tissue, or by bony substance.

SIMPLE VASCULAR TISSUES.

Cellular Tissue.—Cellular pseudo-tissue is one of the most common of adventitious formations, composed of associated white fibrous and yellow fibrous (elastic) fibrils. But rarely does it possess the character of the natural texture in perfection; the distinction of its component filaments is less clear, the fasciculation of these less regular than in the typical structure. A more or less successful attempt at its production is made in all cases, where induration-matter forms, — the highest degree of perfection seems to be attained in old adhesions of serous membranes. A lapse of many months is necessary, however, to mould the new structure into its most perfect attainable form; while on the other hand, a period of seven days (as we have seen in a fatal case of pleurisy) will suffice for the production of an imperfect tissue of this class.

Schwann† found that embryonic cellular tissue yields no glutin; the same fact has been ascertained by Simon‡ in respect of the adventitious cellular tissue of condylomata,— by Gueterbock, in respect of that of granulations. The latter observer found pyin in the water in which the granulation-substance had been boiled. At an early period of formation fibrin is found in association with the principle (tritoxide of protein?) to which the name of pyin has been given; eventually glutin is yielded on ebullition, but it may be doubted whether the chemical constitution of the new, is ever precisely the same as that of the imitated texture.

Serous Tissue.—A single layer of polygonal pavement epithelium, beneath this a basement membrane of singular tenuity, and yet beneath this a stratum of cellular tissue, constitute a serous membrane. This structure is essentially disposed to form shut sacs, and produce and retain a certain secretion. So far we have a texture which is often generated adventitiously; but if, as is now admitted, natural serous tissue is supplied in its proper substance with nerves*, it becomes a complex structure, of which a *perfect adventitious* copy is never generated.

A new serous sac may be produced (*a*) by modification of natural structure, with addition of a new element; or (*b*) be completely adventitious.

(*a*) In this class appear those well known cases in which pressure, with or without friction, causes condensation of cellular tissue with production of epithelium, the latter forming a lining for a sac of the former. So are produced new supernumerary bursæ about the knees, the shoulders of porters, between the skin and bone of stumps, between the skin and spinous processes in spinal curvature, whether primary or from caries, &c.

(*b*) Purely adventitious serous tissue is either (a) laminar or (b) saccular.

(a) By the laminar variety, we understand those strata of pseudo-serous tissue which invest false membranes in serous cavities.

(b) The saccular variety comprehends cysts, *primary* and *secondary*. *Primary* cysts are spontaneously evolved, are capable of indefinite increase in number and size, through some intrinsic force, constitute in themselves the disease where they exist, form the material they contain, are closed on all sides, lined with epithelium, and simple or compound.

Simple cysts occur singly or in clusters, and may appear in almost every region of the body; their walls are of variable thickness and simply cellular, fibrous or calcareous; their contents serous or glairy. The mamma and ovary are the most frequent seats of the clustered simple cyst.

The compound cyst (cystoma) is characterised by its faculty of producing secondary cysts in its walls, — these a tertiary series and so on. Their closest investigator, Dr. Hodgkin, assigns them three chief varieties of form, — the pedunculated, the intermediate, and the broad-based, for a full description of which we must refer the reader to his treatise.† The growth of the contained cysts is sometimes so active, as not only to give a nodulous outline to the main mass (which may attain enormous bulk), but to cause rupture of the walls of the primary cyst. Various morbid changes, inflammatory and other, may arise

* We should be unwilling to affirm that these bodies are *never* truly cartilaginous; but we have examined a considerable number without discovering the chemical or textural qualities of that tissue.

† Untersuchungen, S. 136.

‡ Müller's Archiv, 1839. P. 26.

* Todd and Bowman, Physiol. Anat. p. 130.

† Morbid Anat. of the Ser. and Muc. Membranes, vol. i.

in these productions; carcinoma may even, in predisposed persons, be formed in their *walls*, but not (so far as evidence goes) be produced in their *cavity* as an evolution of blastema exuded from their lining membrane.

Müller has recently applied the name cysto-sarcoma to growths, principally composed of a fibro-vascular texture, but invariably found to contain solitary cysts in their substance. The cysts may be solitary or compound; the solid substance, of greater or less density, has an indistinctly fibrous structure, contains no cells, and is of albuminous basis. This growth is essentially distinct from carcinoma, but that it differs generically from sarcoma seems questionable.

Secondary cysts are not spontaneously generated, but form through the influence of bodies foreign to the site they occupy: around effused blood, after a series of modifications (the apoplectic cyst), around adventitious products, extra-uterine fœtuses, and bodies introduced from without, as musket-balls, shot, pins, &c.

A sort of pseudo-cyst is sometimes produced by distension and closure of small natural cavities, or of the excretory ducts of glands. In the first class we find dilated cutaneous follicles, intestinal crypts, and solitary glands; to the second class belong cysts of the lactiferous and pancreatic tubes, of the labial and sub-maxillary glands, some of those in the testicle, and, it is commonly believed, in the kidney.*

Fibrous and Elastic Pseudo-Tissues.—Of the production of white fibrous-tissue of an imperfect kind, numerous examples have been referred to in the past pages, — it is one of the commonest of new formations.

Less common by far is the generation of the yellow fibrous element, which is distinguished by resisting the action of acetic acid; the mesh-like arrangement of bifurcated fibres is much rarer in the imitation new tissue than in its prototype, — nor does the former occur (so far as we know) in masses of any size. The modification of this texture which constitutes the main element of artery is doubtless produced in new vessels.

Osseous Pseudo-Tissue.—The most perfect imitation of a complex natural texture is exemplified by adventitious bone, — produced for the reparation of injuries (Permanent Callus). It is even said that the permanent callus has all the characters of true bone, — a proposition which appears to us to require more absolute proof than it has yet received. The new bony shaft, produced to supply the ravages of necrosis of the long bones, is a ruder imitation of original bone; it is darker in colour, rough, and tuberculated on the surface, and often much denser than the latter. (See OSTEOMA, p. 134.)

Nervous Pseudo-Tissue.—In certain of the simpler varieties of neuroma the induration-matter mainly forming the tumour appears to contain a larger proportion of tubular fibres, than would in the natural state fall to the share of a portion of nerve of similar length. The tissue in excess (admitting the fact to be substantiated) might, however, be rather regarded as an hypertrophy than a new production.

The regeneration of voluntary nerve (rendered probable by the experiments of Haighton) has been proved by those of Steinrück*, Nasse, Günther†, and Schrön.‡ The tubules produced in the exudation, connecting the cut ends of a nerve, differ from the natural ones in being more widely apart, of smaller diameter, less parallel to each other, more intertwined, and more mixed with cellular fibrils. The time required for their production varies,—a month appears to be the shortest period yet observed; the length of nerve which may be excised is yet unsettled. In the majority of cases, even where reproduction is seemingly perfect, the physiological action of the injured cord remains imperfect; probably because the corresponding parts of the same fibres *are not*, or because sensitive and motor fibres *are*, brought into connection; besides the new tubules are not the *precise* physical counterparts of the old, nor is their number as great as in the original texture.

Cerebral substance removed from animals is replaced by a brain-like matter: the precise nature of this matter (as of that appearing in hernia cerebri in man) has not been examined sufficiently. It seems very doubtful that dynamic vesicular texture ever forms adventitiously.

Blood-vessel.—The development of new blood-vessels, though so common, is but ill understood. They must obviously be produced from pre-existing trunks, or be evolved independently.

Viewed as productions from the old vessels, they have been supposed to be mere prolongations of these, — a notion set aside by the fact that vessels do not terminate by open mouths. Or, again, they have been considered the produce of a looping process — the increased impulse of the circulation towards the site of vascularisation being supposed, when combined with a relaxed state of their own texture, capable of elongating the old trunks into loops: it seems probable that increased vascularity may, to a limited degree, be produced on this plan. Or, again, it has been conjectured that processes, first solid, subsequently hollow, spring from the sides of the original vessels,—an hypothesis unsupported by direct evidence and deficient in plausibility. Or, lastly, it has been maintained that the first step in the process consists of rupture of original

* Cystic productions in the kidney still require investigation — from the minute apparently solitary cyst, to those clustered masses causing destruction, more or less complete, of the proper renal substance. Dr. Johnson (Med. Chir. Trans. vol. xxx.) adduces arguments of a novel kind to prove that the simple cyst is in reality a dilated tube; Mr. Simon (eod. tom.) seeks to show that it is a new development within the parenchyma.

* De Nerv. Regenerat. Berol. 1838.
† Müller's Archiv. Heft V. S. 405. 1839.
‡ Müller's Archiv. 1840.

vessels; the second in the extravasation of blood; the third in the passage of this into canals (manufactured, as it were, for its reception); the fourth in the formation of walls round this blood: the difficulty in this hypothesis lies in the alleged canal-formation.

The notion that new vessels are independent productions is supported:—by the analogy of the process in the vascular area of the chick; by the fact that the new cannot at first be injected from the old vessels; by the analogical fact that new blood-particles appearing in lymph in the frog are of spherical shape (as in the fœtal condition), and are therefore not particles previously contained (for these are oval) in the old vessels; by direct observation both with the naked eye and with the microscope. In truth in one spot of a new material to be vascularized may be seen minute unconnected points of blood; at another, a number of such points united in linear juxtaposition, so as to form a streak of blood unenclosed in any distinct vessel; elsewhere a vascular investment is found for a similar streak; further on a like piece of delicate tube divides at each extremity into a number of tapering ramifications, assuming a stellate arrangement, the whole assimilable to the system of the portal vein, and capable of effecting an independent *oscillation* of the contained blood. What is thus seen with the naked eye is corroborated with the microscope; but this instrument has not yet made clear either the precise structural characters or developmental process of the new vessels: we simply know that these are wider, and of thinner walls than natural capillaries. The manner in which communication is effected between old and new vessels (when the latter first become the seat of true *circulation*) is unknown. That the formation of new blood precedes that of new vessels seems fully established; just as the cell-structure, destined to fill a loculus in a new growth, forms before the loculus-walls that contain it.

The production of new blood and vessels signifies the appearance of various new chemical compounds in the vascularized material; the globulin formation may be understood, that of the hæmatin is at present inexplicable, —unless we accept the extravasation-theory above referred to, which supplies iron as required.

Further observations are wanting as to the shortest possible time in which new vessels may be formed; we have seen them in peritonæal exudation aged seven days; Everard Home speaks of their appearance in twenty-nine hours. They form in growths, induration-matter, hypertrophy of natural textures, and pseudo-tissues. Generally produced on a limited, they in rare instances form on an extensive scale; the most singular illustration of the latter appears in the new system of vessels generated in tuberculized lungs (Schroeder, Guillot), which effects not only a complete change in the anatomical condition, but in the physiological actions, of those organs.*

* Louis on Phthisis, ed. cit. p. 29.

Erectile Tissue. — (See ANGEIECTOMA, p. 128.)

Lymph Vessel. — Schroeder van der Kolk has described lymph vessels of new formation in peritoneal pseudo-membrane; it is generally admitted that his observations require corroboration, and we know of no other evidence bearing on the question.

Fibrous and Spongy Cartilage.—Fibro-cartilage forms in some rare instances the material by which imperfect union of bone is effected; its own losses are supplied by a similar material; it does not appear to form in an absolutely adventitious manner. Nor does spongy cartilage grow as a new product,—and of the reparation of this texture little is known.

Hair.—The adventitious production of hairs is not singularly rare, and though, no doubt, much fantastic matter has been written on their places of attachment, the following localisations may be admitted as real. The tongue*, the caruncula lachrymalis, the cornea†, the internal surface of the gall-bladder‡, the nymphæ, the vagina, (in connection with fat) tumours of the uterus and of the fauces.§ Cases of defecation of hair and of pilimiction are for obvious reasons to be received with distrust ||; but the rupture of an ovarian cyst into the bladder may sometimes have caused discharge of hair with the urine.

Cysts of new formation are the favourite site of adventitious hair; pilous cysts have been seen occupying the ovary, uterus, subcutaneous membrane, muscular substance, walls of the stomach, testicle, liver, thyroid gland, omentum, and peritonæal cavity. The ovarian is of all cysts the most frequent abode of these productions. The hair is scattered through the fatty matter generally present, or adherent to the walls of the cyst, either by a bulb or by simple embedding, or by means of cretaceous particles. The colour of the hairs varies greatly, sometimes even in the same cyst; their length from a few lines to upwards of two feet. They commonly resemble in structure the hairs of the head, rarely those of the pubis: their possession of roots has been denied; whereas Meckel considers it probable that they always have a root in the outset, losing it subsequently after separation from their seat of attachment.

Tooth. — Teeth are frequently found in pilo-fatty cysts; there scarcely appears, indeed, to be a single authentic case of the discovery of adventitious teeth (except where produced

* This has been denied hypothetically; yet nothing is less improbable than the occasional growth of obvious hairs from this organ, seeing that some of the epithelial processes of the conical papillæ actually enclose minute hairs in the natural state. (See Todd and Bowman, Anatomy, vol. i. p. 440.)

† Gazelles, Journal de Méd. t. xxiv. p. 332.

‡ Of more than an inch in length, by Bichat. Anat. Gén. t. iv.

§ Ford, Medical Communications, vol. i. p. 444. 1784.

|| Yet what is to be said of the case related by Henry (Med. Chir. Trans. vol. x. p. 142. 1819) of a middle-aged *man*, who voided hairs of from $\frac{1}{10}$ of an inch to an inch in length with the urine, some of them occasionally coated with uric acid?

in, or close to the mouth) without coexistent hairs. Nails and true cutaneous texture are frequently present also. As transition-stages to the purely adventitious formation of teeth appear: the growth of supernumerary teeth in the jaws; of such teeth not in the jaws, but still in the cavity of the mouth; of such teeth in the neighbourhood of the mouth, as in the orbit.* Appearing in the mediastinum†, close to the diaphragm‡, in the stomach§, in the testicle, &c., they are purely adventitious. The ovarian cyst is their chosen seat, however, and their number may be very considerable. In an ovarian cyst now before us (Univ. Coll. Mus.), there are three separate sets of teeth; in the one are 2 molars, 2 bicuspidati, and 2 canines; in the second, 2 molars, and 1 incisor; in the third, 6 molars, 2 bicuspidati, 2 canine, and 1 incisor, — 20 in all. A case has been recorded by Ploucqnet and Autenrieth of a young sterile woman, in whom an ovarian cyst contained 300 teeth, — a fact showing that the relationship (contended for by Meckel and others) between the combined number and character of adventitious and natural teeth is imaginary.

The full consideration of the mode of development and production of adventitious teeth and hair would carry us into the regions of Teratology; and it must be confessed that the most diligent investigators have failed to find explanations for all cases. If it be true that in some instances these products are the residual parts of a regularly-formed fœtus, in others evidences of an attempt to produce a fœtus (in either of which cases they may be the proceeds either of extra-uterine pregnancy or of the formation of a monster by inclusion), it is also certain, that in other instances all explanations hitherto tendered have failed of their mark.

Cutaneous. — Except in such cysts as those just referred to, skin is never formed adventitiously. Losses of this texture are repaired by a substance partaking of the characters of induration-matter and of fibrous tissue.

Mucous. — Portions of mucous membrane destroyed by ulceration are replaced by induration-matter, covered on the free surface with a coating of epithelium, smooth and glistening; the border is, or is not, puckered and finely nodulated. The attempts made by Sebastian, Dr. Parkes ||, and others, to show that the reparative power goes the length of forming new intestinal mucous texture, the precise anatomical counterpart of the old, appear to us to have failed; nor is there any evidence that the cicatrix (either of the flat or puckered variety) can even rudely discharge the office of the texture it replaces.

The pyogenic membrane of chronic abscesses, tuberculous cavities and fistulæ, has many of the more obvious characteristics of mucous membrane. Of velvety look and feel; varying (like its prototype) in colour from red to grey, slaty, or even black; thick as the inner coat of the stomach, or thin as the lining of the frontal sinuses; more or less closely adherent to a stratum of induration-matter (representing the submucous cellular membrane of health), and covered with epithelium; capable of producing fungous vegetation from its surface; and utterly inapt to contract adhesions with itself; — this structure has evidently many claims to the title of *pseudo-mucous.* Its deficiency in villi and follicles simply proves that it imitates the least highly elaborated of nature's types. The microscopical characters of this formation, however, require full examination.

Glandular. — Destroyed glandular texture is not reproduced; much less does a *de novo* development of such texture lie within the range of morbid action.

Muscle. — There is no evidence that *striped* muscular fibre is produced for purposes of reparation, much less as a wholly adventitious formation.

Unstriped fibres occurring in the ureter, walls of the gall bladder, and other excretory organs, are rather hypertrophous, than adventitious, products, inasmuch as they naturally exist in minute quantity in those organs. Of the truly adventitious production of this fibre nothing is satisfactorily known.

SUB-CLASS II.

GERM-FORMATIONS OR PARASITES.

Products, whose continued existence does not depend upon *direct* access of nutrient fluid from the organism they inhabit; which spring from a germ*, and simply live in, without forming part of, the individual they infest, are true Parasites. They do not in themselves constitute disease, but always indicate its presence, and sometimes entail its development; in the latter case they may be made to propagate similar disease from organism to organism. In some rare instances the organic kingdom to which they belong is doubtful; the great majority easily take their places among animals or vegetables.

ORDER I. — ANIMAL PARASITES.

See ENTOZOA (vol. ii.).

ORDER II. — VEGETABLE PARASITES.

Vegetable parasites form on the skin, on mucous membrane, on new surfaces, upon or within the body, and in certain of the fluids. They indicate the existence (on the surface, or in the fluid, affording them a habitation) of the presence of chemical decomposition, and also of the presence of some new material (albuminous, saccharine, &c.), the result of diseased action. Their precise influence and pathological power in the human subject are yet

* Barnes, Med. Chir. Trans. vol. iv. p. 316.
† Gordon, Med. Chir. Trans. vol. xiii. p. 12. 1825.
‡ Berlin, Sammlung, t. iii. p. 264.
§ Ruysch, Hist. Anat. Med. dec. III. No. i. p. 2.
|| On the Dysentery and Hepatitis of India.

* We set aside the notion of equivocal generation, inasmuch as observation, so far as it goes, deposes to the necessity (at least the *existing necessity*) of propagation from germs.

open to inquiry, but it is certain that the difficulty of killing them obstructs the cure of diseased states (porrigo favosa, for instance), in connection with which they form. They are referrible to fungi and algæ, and commonly composed of cells arranged in a moniliform manner, and multiplying by gemmules. When forming on the external surface, they may be called epiphyta; when within the frame, entophyta.

The torula has been observed in the urine and in the gastric fluids (Busk) of persons labouring under saccharine diabetes; also in the fæces, and in vomited fluids under various conditions. Three to five rounded or oval cells, upon which acetic acid produces no appreciable effect, provided sometimes with gemmules (single or more than one),—gemmules differing from themselves simply by being smaller,—the torula of the human subject is in all respects exactly like the torula cerevisiæ, and signifies the presence of fermentating matters.

Mycodermatous vegetations occur as elements of the crust of porrigo favosa; they germinate underneath (and never upon) the epidermis in amorphous exudation of protein-basis thrown out by the cutis. Underneath the epidermis, covering the capsule, lies the amorphous exudation-matter in a thin layer; beneath this, jointed cylindrical tubes, matted together with similar matter; deeper still, fragments of tubes; and yet further, free sporules in abundance: the elongated cells, forming the tubes, occasionally contain molecules,—these are visible when magnified 800 diameters.* Acetic acid, by lessening the opacity of the amorphous matter, renders the cells and tubes more distinct. Attempts to propagate favus by inoculation of the sporules, the matter of the crust, and the fluid of the pustules, have failed (Gruby, Bennett); whether plants, healthy persons, or persons affected with porrigo, have been made the subjects of experiment: failures appearing to show that the parasite is incapable of germinating unless in a special soil (the amorphous exudation-matter), and that the production of this soil constitutes the essence of the disease. Even when the special constitutional state exists, artificial introduction of the sporules will not call forth exudation-matter of the quality fit for their nourishment; for inoculation of an affected scalp fails as completely as that of the skin of a healthy person. So, too, the cell of cancer must have its soil of kindred blastema, or the inoculation of its germs will fail. (See p. 124.)

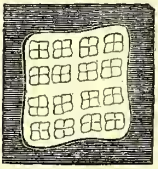
In plica polonica Günsburg† found sporules in the substance of the hair-roots; Dr. Münter failed in discovering them,—they are therefore not essential. Gruby detected epiphytes in sycosis between the root of the hair and its sheath.

Speaking of entophytic development on diphtheritic exudation of the mucous membranes and skin in a former page (p. 118), the misplacement of a word gives us the appearance of saying that vegetable growth is less common in thrush than in the similar exudation in phthisis, whereas we meant to affirm the contrary.

Dr. Bennett contributes an example of entophytic growth found amid the sputa, and in the contents of cavities, in a case of phthisis: we have ourselves seen jointed vegetable filaments on the walls of cavities.

In the fluid of pyrosis Mr. Goodsir* found a living structure closely allied to certain genera of Bacillariæ, but most closely to the genus Gonium, among the Volvocinæ; looking like a wool-pack (hence the name *Sarcina ventriculi*), bound with cord, crossing it four times at right angles, and at equal distances; varying in diameter from $\frac{1}{800}$ to $\frac{1}{1000}$ of an inch, and consisting (*fig.* 99) of sixteen four-celled frustules embedded in a square tablet of a transparent texture.

Fig. 99.



The Sarcina ventriculi.

GROUP II.

LIQUID ADVENTITIOUS PRODUCTS.

Fluids formed in localities, naturally free from them, are obviously adventitious. Pathologically considered, fluid products are of signal importance; but the consideration of their morbid anatomy will not long detain us.

These fluids accumulate in serous cavities (dropsical); in the cellular membrane (œdema or anasarca); or in the parenchyma of organs (œdema). They may likewise form in adventitious seats, as in cysts, and in the bullæ of erysipelas, rupia and pemphigus, sudamina, &c. When pure, the fluid of dropsy of serous membranes is aqueous, transparent, free from viscidity, and colourless, or faintly yellowish. But it may be thicker, ropy, and of deeper colour,—and is commonly so in ascitic or ovarian fluid, which has been for any length of time accumulating. Especially in cases of this class, organic corpuscles may be found; otherwise the fluid is transparent and amorphous under the microscope. In the fluid of syphilitic rupia we have found well-constituted exudation-cells.

Generally speaking the fluid of dropsy is alkaline,—we have never known it otherwise; but it certainly is occasionally neutral or even acid. In chemical composition it corresponds

* H. Bennett in Trans. Roy. Soc. of Edin. vol. xv. part ii. 1842; see also Gruby, Comptes Rendus, 1841, 1842, and 1844.

† Müller's Archiv. 1845. p. 34.

* Edinb. Med. and Surg. Journal, vol. 57. pl. 7 fig. 2.

very closely with the serum of the blood,— its essential protein-ingredient being albumen in the state of albuminate of soda. As various degrees of inspissation of the fluid occur, the ratio of the solid ingredients to the water varies within rather wide limits. Accidental constituents are biliphæin, urea, and hæmatin. Fat is always present; and scales of cholestein (visible to the naked eye) are not very unfrequent, especially in dropsy of the tunica vaginalis. Epithelial cells are to be seen in small quantities (and we have found these calcified): there is no reason to believe that an excessive quantity of epithelium is necessarily a part of the disease, though in some cases milkiness or a puriform look may be caused by their extreme abundance. Pus and blood corpuscles may be accidentally present.

The fluid of true dropsy is distinguishable by the deficiency of developmental power: it never forms a blastema for cell-growth; neither is it capable of spontaneous coagulation. But in some rare instances fibrin escapes along with the serum of the blood,—and this in notable quantity. The fluid then becomes coagulable; but it is a mystery why (sometimes occurring within the body) its coagulation sometimes does not occur until some hours after its removal from the body. We have seen the contents of the pleura, perfectly fluid when first exposed, become distinctly clotty within an hour and a half: similar occurrences have been witnessed by others. When coagulation takes place within the body, the coagulum may probably act as a blastema. The cause and mechanism of this escape of fibrin from the vessels, and its relationship to inflammation are utterly unknown. In a former place (p. 93) we have spoken of the occasional excretion of fibrin with the urine.

GROUP III.

GASEOUS ADVENTITIOUS PRODUCTS.

If the precise signification given to the term Adventitious Product be considered, it will be seen that gaseous matters are only truly *adventitious* when *foreign in nature* to the textures *producing* them. Air entering veins lying within the suction-influence of the chest; air swallowed; air entering the uterus and bladder from without; and air diffused through the cellular membrane, serous cavities, or parenchymatous organs, and derived from the air passages or alimentary canal, through a wound, ulceration, perforation or rupture of these; consequently find no place under the present head. We shall here confine ourselves to a notice of gases produced by (*a*) local or general anti-cadaveric decomposition, and (*b*) an alleged process of secretion.

(*a*) A man, aged twenty-five, died on the sixteenth day of continued fever (Peyerian type), and was examined by M. Bally *eight* hours after death. The body was soiled with blood, which had transuded through the skin of the thighs and scalp, and there was universal emphysema. The mesenteric glands contained gas which, like that in other parts of the body, took fire and exploded, when brought in contact with the flame of a taper; in burning it formed a tuft with a blue base and white apex, and appears to have consisted of proto-carburet of hydrogen, one of the ordinary products of putrefaction, and is presumed to have been formed before death. (Art. EMPHYSEMA, Cyclopæd. of Surgery, vol. ii. p. 85.) Dr. Mouat (Ed. Med. and Surg. Journal, vol. liii. p. 427. 1840) has published a case in which gas was found in the cellular tissue of the right thigh, on the surface of the pericardium and pia mater, and in the right side of the heart and femoral vein. Accumulation of gas from decomposition of fluid in the pleura, pericardium, peritoneum, joints, and tunica-vaginalis, has been described by various persons: hydropneumothorax, however, it is to be remembered, without perforation of the lung, is certainly of excessive rarity.

(*b*) It occasionally happens, as was first, we believe, noticed by Dr. Graves, that at a certain period of the progress of pneumonia, the percussion-signs of pneumothorax may be discovered. Within the last year we have had in our wards a most interesting case of pure and simple pneumonia, unattended with the formation even of dry plastic matter in the pleura, during the progress of which a perfect tympanitic note (quite distinct from an amphoric or tubular one) continued for some time producible over the affected lung. The only mode of accounting for it seemed by admitting the presence of air in the pleura, — and if such were the fact, that air must have been the produce of secretion. A singular case is recorded by Sir F. Smith *, in which a secretion of gas from the skin appears to have taken place.

(*c*) It is not uncommon to find bubbles of gas in the veins of the pia-mater, and their presence is not easily explicable. If the gas be regarded as of putrefactive origin, the difficulty is to explain why it occurs in bodies perfectly free from ordinary evidence of putrefaction, and why it is limited to those particular veins. If it be regarded as natural gas of the blood extricated during life, how comes it, that the blood in that particular part only should present it after death, and how comes it that, if really extricated *there*, it had not been carried on with the circulating fluid to the *heart?* The quantity of gas is too small in such cases to admit of analysis, — else perhaps a comparison between it and the gases of venous blood might throw some light on the matter.

But next comes the curious fact that where there is least blood there is most intra-venous air, — that is, where there is most of the presumed cause, there is least of the presumed effect. It is, in fact, in persons, who have died from hæmorrhage, that air has been found in greatest abundance in the veins. Lieutaud † relates the case of a girl who died

* Dub. Med. Journal, vol. xviii. p. 457.
† Hist. Anat. Med. Obs. 55.

suddenly in a state of syncope, after having been repeatedly bled, and in whom the cerebral veins and choroid plexus were found full of air. M. Rerolle* has published several cases of the kind, where profuse hæmorrhage had existed; in one of fatal epistaxis, the heart, arteries, and veins, contained large quantities of air. Another of these is rendered particularly remarkable by the fact that the gas (subcutaneous) took fire with slight detonation (as in M. Bally's case), and burned with a bluish flame; here the patient had died of hæmorrhage after removal of a tumour from the back, and was examined six hours after death, the thermometer (Réaum.) marking only + 2°. Similarly Dr. Graves has noticed emphysema of the abdominal parietes in a sufferer from frequent epistaxis.

In all this there is much mystery. M. Rerolle conjectures that, in such cases, air is absorbed by the radicles of the pulmonary veins, — the air would then have no claim to be considered adventitious, and the hypothesis is, perhaps, not to be rudely rejected.

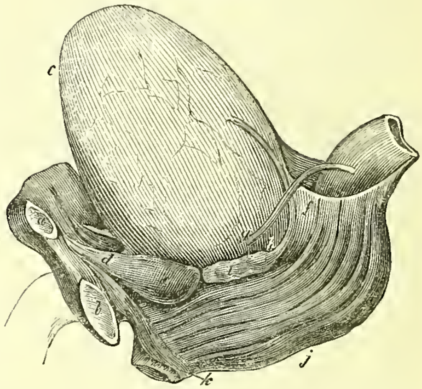
(*Walter Hayle Walshe.*)

PROSTATE GLAND. (*Corpus glandulosum;* Προστάτης, Gr.; *die Vorsteherdruse,* Germ.; *La Prostate,* Fr.).—The prostate is a glandular body surrounding the neck of the bladder and beginning of the urethra of the male, deriving its name from its position in front of the vesiculæ seminales. It is situated in the anterior part of the pelvis, behind and below the level of the symphysis pubis, posterior to the triangular ligament of the urethra, with which it is connected by a continuation of the latter with its capsule. It has the membranous part of the urethra in front of it, and somewhat below its level, and it rests upon the anterior surface of the middle of the rectum. The prostate is perforated by the urethra, two thirds of the gland are below this canal; it inclines obliquely downwards and forwards from behind, its apex being situated rather below the base.

In shape the prostate resembles a Spanish chesnut, or the ace of hearts on playing cards, and presents a base behind and an apex in front; it is compressed from before backwards; its sides are convex, and its base is notched. From base to apex the prostate measures from an inch to an inch and a quarter; from side to side, from an inch and a half to two inches; and from half an inch to an inch in depth from before backwards: a healthy prostate weighs five or six drachms. This measurement nearly accords with that given by Dupuytren, who devoted much attention to this subject, as having a most important bearing upon the bilateral operation of lithotomy.

A correct knowledge of the relations of this body to the adjacent viscera is of the highest practical importance. If, after the introduction of a catheter through the urethra into the bladder, the finger be passed into the rectum, and carried forward, the bulb of the urethra is first indistinctly felt, behind which is the membranous portion; whilst beyond this, and still within reach of the finger, the prostate is perceived. In the empty state of the bladder the outline of this body is usually distinct enough; but when the bladder is over distended with urine it becomes in a great measure confounded with the posterior surface of this viscus, and cannot be easily distinguished. To obtain a good view of the connections of the prostate, a side view of the pelvis should

Fig. 100.



a, os pubis; *b*, ischium; *c*, bladder; *d*, ligaments of the prostate; *e*, prostate gland; *f*, posterior false ligaments of the bladder; *g*, ureter; *h*, vas deferens; *i*, left vesicula seminalis; *j*, rectum; *k*, a small portion of levatorani.

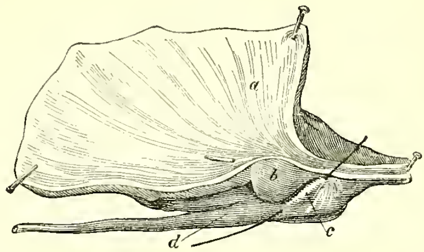
be prepared in the ordinary manner, by the removal of the left os innominatum, with the soft structures in immediate connection with it, leaving a small portion of the symphysis and ramus of the os pubis, together with the spine and a part of the ramus of the ischium. In this manner the levator ani is first brought into view, at the upper edge of which is seen the point of division of the pelvic fascia into the vesical and obturator. The levator ani has no immediate connection with the prostate, for, although it gives it a general lateral support, it is separated from it by the vesical fascia. Internal to the levator ani lie the vesical fascia and the levator prostatæ muscle. The vesical fascia is continuous with the pelvic, it passes inwards over the prostate, rectum, and bladder, inclosing these structures in separate sheaths. Thus the prostate gets a complete investment from it; this covering is above continuous with the anterior true ligaments of the bladder, in front it is connected with the posterior layer of the deep perinæal fascia, and beneath, the fascia passes between the gland and the rectum; thus the gland is completely invested by a fibrous capsule. This envelope incloses within it the prostatic plexus of veins, and the blood-vessels and nerves of the prostate; the veins are continuous in front with the dorsal

* Thèses de Paris, No. 129. 1832.

vein of the penis, and behind with branches terminating in the internal iliac vein. Many branches of the prostatic venous plexus are necessarily divided in the lateral operation for the stone; and in old persons, from their increased size, they occasionally pour out so large a quantity of blood as to endanger the life of the patient. They often contain calculous concretions, to which the term phlebolithes has been given. The following is the mode of connection between the prostate and the coats of the bladder; the mucous coat is of course continuous from the bladder to the urethra; the submucous cellular coat is firmly adherent to the capsule of the gland, whilst the inferior fibres of the detrusor urinæ are arranged thus, the longitudinal fibres split into two layers, one, the thickest, adheres to the submucous cellular coat of the bladder just behind the prostate; and the other, thin and indistinct, is implanted into the base of the gland itself. Harrison has described a long, delicate, and distinct band of muscular fibres as entering the notch in the base of the gland, beneath the uvula vesicæ and middle lobe, into which it is sometimes inserted; but it can frequently be traced nearly an inch further to be inserted into the veru montanum.* I cannot satisfy myself of the existence of any muscular fibres at the under surface of the prostate. On either side of the gland we perceive a muscle, the *levator prostatæ*. It is frequently confounded with the anterior edge of the levator ani, from which however it is occasionally separated by a layer of cellular tissue. It arises from the posterior part of the symphysis pubis by a tendinous slip, and its origin extends for a short distance backwards from the anterior true ligament of the bladder of the corresponding side; as it descends, its fibres spread out over the side of the prostate, and are inserted into the under part of its capsule; its use is to support the gland, and by compressing it laterally to assist in the evacuation of its ducts. The prostate rests on the anterior surface of the rectum, a thin layer of fascia passing underneath the gland and the vesiculæ seminales. Behind the prostate are the vesiculæ, which diverge from each other as they recede, and are in front received into the interval between the lateral lobes, their anterior extremities are placed beneath the third lobe; the vasa deferentia run on their inner side, and the common ejaculatory ducts pass upwards in a curved direction, between the lateral and middle lobes, to terminate by the side of the sinus pocularis.

The anterior surface, which is grooved by a shallow longitudinal depression, is attached to the back part of the symphysis pubis on either side by two ligamentous or tendinous bands, which are continuous with the capsule of the gland below, and above with the true anterior ligaments of the bladder; they are termed the *ligamenta pubo-prostatica media et lateralia;* they serve to support

Fig. 101.



a, bladder; *b*, section of the middle lobe of the prostate; *c*, left vas ejaculatorium; *d*, left vas deferens.

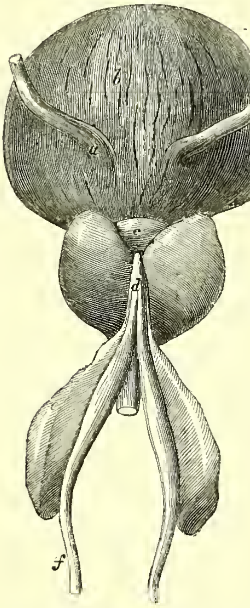
the prostate and sling it to the pubis, thus contributing to the support of the neck of the bladder. The posterior surface of the prostate is smooth and is traversed by a longitudinal depression, at the bottom of which two smaller grooves are visible, inclining towards each other in front, they bound two sides of a small triangular portion of the gland; this is the under surface of the third lobe, on either side of which a *vas ejaculatorium* takes its course.

The prostate is surrounded by a dense capsule derived from the vesical fascia; this gives it a complete investment, and adheres so firmly to the tissue of the gland as to be separated from it with great difficulty. It is divisible into two layers, between which the prostatic plexus of veins runs. The gland itself is of a lightish brown colour, of a fleshy feel, and when cut it offers the resistance of soft cartilage: it is one of the firmest glands in the body. It is principally formed of two lateral lobes, a right and a left, of equal size in the healthy condition, of an ovoid shape, with their long axes from before backwards; they diverge from each other behind, leaving an interval between them, already mentioned; the lateral lobes are connected together beneath the urethra by an isthmus of variable depth and breadth. Between the two lateral lobes, which make up the bulk of the gland, we find the middle or third lobe. The name of Sir Everard Home is usually associated with the description of this lobe. Although not the discoverer of it, he gave the first full description of it. Mr. (now Sir Benjamin) Brodie made dissections of it under Home's direction; in the first subject in which it was examined, it appeared as a distinct gland, resembling Cowper's gland in size and shape; but in the examination of this body in five different subjects, the appearance was not the same in any two of them. The following is the account given by Home of what he considers the most natural condition of this part of the prostate; —"On turning off the vasa deferentia and vesiculæ seminales, exactly in the middle of the sulcus, between the two lateral portions of the prostate gland, there was a round, pro-

* See Art. Bladder, vol. i. p. 381.; and for description of the arrangement of the circular fibres, see the same article.

minent body, the base of which adhered to the coats of the bladder. It was imbedded not only between the vasa deferentia and the bladder, but also in some measure between the lateral portions of the prostate gland and the bladder, since they were in part spread over it, so as to prevent its circumference from being seen, and they adhered so closely as to require dissection to remove them; nor could this be done beyond a certain extent, after which the same substance was continued from the one to the other. This proved to be a lobe of the prostate gland; its middle had a rounded form, united to the gland at the base next the bladder, but rendered a separate lobe by two fissures on its opposite surface. Its ducts passed directly through the coats of the bladder on which it lay, and opened immediately behind the veru montanum."

Fig. 102.



A posterior view of the bladder and prostate, with third lobe; the vasa ejaculatoria and vesiculæ are thrown forwards. (*From Sir E. Home.*)

a, ureter; *b*, bladder; *c*, third lobe of prostate; *d*, vas ejaculatorium, turned forwards; *e*, vesicula seminalis; *f*, vas deferens.

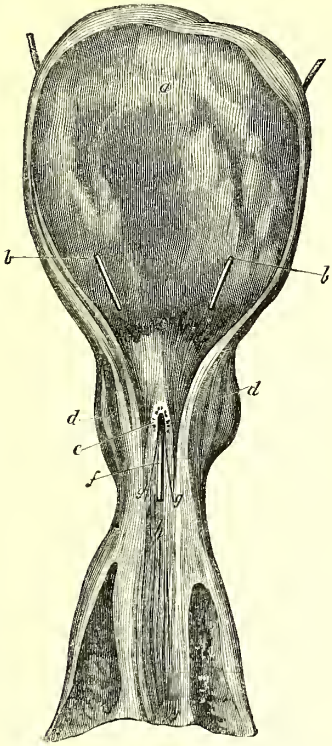
It is well known that Hunter was aware of the existence of this lobe as a natural constituent of the prostate, for he says, " A small portion of it (the prostate) which lies behind the very beginning of the urethra, swells forward like a point, as it were, into the bladder; acting like a valve to the mouth of the urethra, which can be seen even when the swelling is not considerable, by looking on the mouth of the urethra, from the cavity of the bladder in the dead body. It sometimes increases so much, as to form a tumor projecting into the cavity of the bladder some inches." Hunter has given an accurate drawing of the middle lobe of the prostate. In the normal state it represents a simple elevation of glandular structure beneath the uvula vesicæ, between the two lateral lobes at the back part, and connected laterally with them; but it varies materially in size and consistence in different subjects. I have no doubt that in some cases it is wanting altogether, in others it is of small size; and in many, where it is well developed, it is as firm and consistent as the other parts of the prostate. In one example which I examined, it was much firmer than the lateral lobes, and of a much lighter colour; indeed, so distinct did it appear that I really doubted whether it belonged to the prostate. I applied a microscopical test, and found its ducts charged with similar concretions to what have been so frequently found in other parts of the gland; this proved to me that it was a part of the gland itself. The best method of viewing the third lobe is to make a vertical section from before backwards through it, and to carry the incision directly through the *veru montanum*, *sinus pocularis*, urethra, and inferior part or isthmus of the prostate, the divided third lobe is thus brought into view, as well as the ejaculatory duct of one side, passing between it and the lateral lobe. The sinus pocularis runs beneath it (see *fig.* 101).

The urethra traverses the prostate from behind forwards, and is completely surrounded by it. Amussat doubted this fact, and thought that only three fourths of the canal were encircled by the prostate, and that the remaining fourth (the anterior) was covered by a cellular or muscular medium, extending from one lobe to the other. This is undoubtedly incorrect as a general rule, for I have examined with the microscope that portion of the gland placed over the upper surface of the urethra, and found it identical in structure with the remainder of the organ. The urethra in passing through the prostate is dilated into a considerable sinus, and presents in front a triangular opening if a transverse section be made. It is not exactly in the centre, being nearer the anterior than the posterior surface; it is generally said to be about two lines distant from the former, and four from the latter, and seven from the lateral surface of the gland. It varies frequently in this respect in a marked degree. When the third lobe is small and flat it is much nearer the posterior surface than the anterior; and this is the case where the isthmus or medium of connection beneath, is thin, a condition not very uncommon. The prostatic portion of the urethra is about fifteen lines in length, and is wider in the middle than at either extremity; it contains within it the veru montanum or caput gallinaginis, which runs along it, forming a conical elevation, and dividing it into two equal portions.

Over the urethral surface of the third or middle lobe of the prostate, the mucous membrane is raised up so as in some subjects to form a remarkable elevation, lying transversely at the beginning of the urethra; this

is especially seen in old subjects: it corresponds with the anterior extremity of the

Fig. 103.



Front view of the bladder and prostate.

a, bladder; *b*, ureters; *c*, uvula vesicæ; *d*, prostate gland; *e*, openings of prostatic ducts; *f*, a probe passed into the sinus pocularis; *g*, *g*, bristles in vasa ejaculatorium; *h*, membraneous portion of urethra.

trigonum vesicæ, and is known by the names of the *uvula vesicæ*, *luette vésicale*, *valvula pylorica* of Amussat. In the healthy state of the bladder and prostate, this elevation is frequently scarcely perceptible, unless the bladder is much contracted; but it is subject to considerable increase in size, and is generally involved in those cases of enlarged prostate which are of such frequent occurrence in the old person, and where the third lobe is the seat of hypertrophy. Mercier describes this vesico-urethral valve as a semicircular fold, raised suddenly at a right angle from the posterior surface of the neck of the bladder, and composed of a tissue somewhat resembling muscle; and Mr. Guthrie, in his lectures delivered at the College of Surgeons in the year 1830, directed attention to it as frequently the seat of disease totally independent of any enlargement of the third lobe of the prostate; but to this I shall again direct attention when the morbid anatomy of the prostate is under consideration.

Intimate Structure.—The prostate comes under that division of the glandular system, inappropriately termed conglomerate. Müller places it in his fourth order of glands—"*glandulæ ex cellulorum contextu spongioso compositæ, mediis cellulis in ductus excretorios hiantibus, sine lobulorum divisione composita.*" It is arranged by Cuvier under the head of supplementary glands of the male organs of generation. The external covering of the gland, derived, as already described, from the vesical fascia, having been removed, we come to a deeper layer, which closely surrounds the glandular tissue; it is most intimately connected with it, so as to be detached with the greatest possible difficulty, and can evidently be shown to send processes into the gland, which are probably continuous with the fibrous tissue between the follicles. On the surface of this the lymphatics of the gland are seen to ramify: this is best shown after previous immersion in water. If a simple section is made, the gland presents a spongy cellular aspect, and an opaque fluid oozes out from the cut surface; but its intimate structure can only be made out by microscopical examination of thin sections, or by injections with mercury or coloured size, or by inflation; the outline of its follicles may, however, be seen by a minute injection of its blood vessels, which ramify in a delicate plexiform manner on their surface. It is not a gland of much complexity of structure or arrangement. Briefly, it may be said to be composed of minute terminal follicles, opening into canals or tubes, which unite together to form ducts, which open in an oblique manner on the prostatic portion of the urethra. The orifices of the prostatic ducts are situated principally close to and around the most elevated portion of the veru montanum, in the form of a crescent, the larger ducts on the side, and the smaller on the posterior aspect of this body If a longitudinal, vertical section is made, many of the ducts of the prostate are seen passing upwards, towards the under part of the veru montanum, in a straight direction: the interior of some of them being slit open in the section, whilst others pass obliquely beneath the mucous membrane for some distance prior to their termination. They vary in number from ten to fourteen, but as many as thirty have been seen. Their diameter ranges from one-sixth to one-fourth of a line. It sometimes happens that two or more ducts unite, and open by one common orifice, large enough to admit the end of a small probe.

To unravel the structure of the gland, it is requisite to inject the ducts separately, as the follicles to which they lead have no communication with each other, as the representation given by Müller would lead one to imagine; each duct will be found to give off tubes, which passing in a straight direction, separate gradually from each other, and terminate in minute cells or follicles, which, according to Weber, range from one-sixteenth to one-twelfth of a line in diameter. Müller says that the larger cells are visible to the naked eye, and that with a simple microscope the smaller cells, situated within the larger, and formed of an exceedingly delicate membrane

can be seen; the cellular structure is rendered perceptible by inflation from the ducts. Mr. John Quekett has injected with coloured size, and examined the tubes and follicles of the prostate with the microscope, and represents the latter as varying in size in different parts of the gland; he thinks that one-hundredth of an inch is their average diameter, and has delineated them as is shown in *fig.* 104. Henle

Fig. 104.

has found them to be lined by a delicate pavement epithelium, and at the commencement of the duct he has seen a cylindrical epithelium. Mr. Quekett has traced an intermediate cellular or fibrous tissue, filling up the spaces between the follicles or lobules, and connecting them together. According to Dr. C. H. Jones, "this principally consists of the white fibrous element, but also contains numerous bands, resembling closely those of organic muscle."* The latter anatomist thinks that the enlargement of the gland in hypertrophy of the prostate, is due to an increase in this tissue: he regards the prostate as an assemblage of secerning follicles rather than as a really conglomerate gland.

The arteries of the prostate are usually derived from the vesical and hæmorrhoidal branches of the internal pudic, and from the middle hæmorrhoidal of the internal iliac, which, entering the gland on either side beneath its capsule, are distributed in the form of a network on the parietes of its tubes and follicles; the veins terminate in the vesical and hæmorrhoidal veins: its nerves, which are extremely small, are branches of the hypogastric plexus of the great sympathetic. The lymphatics consist of a superficial and deep set, and pass into the hypogastric ganglia. It happens occasionally that an artery of considerable magnitude runs on either side of the prostate, from the internal iliac, and becomes the artery of the bulb of the urethra. This variety has been seen by Haller, Burns, and Barclay. I have witnessed a similar distribution myself. Dr. Monro met with a case, in which an irregular vessel came from the internal iliac, passed along the lateral and inferior surface of the bladder, pierced the ilio-vesical fascia, ran along the lateral lobe of the prostate, and divided into three branches, one to the dorsum, one to the crus penis, and another to the bulb. Other varieties in the course and distribution of the branches of the internal iliac, involving the prostate, have been occasionally met with, and I allude to them here as points of great interest in respect to the surgical anatomy of this body.

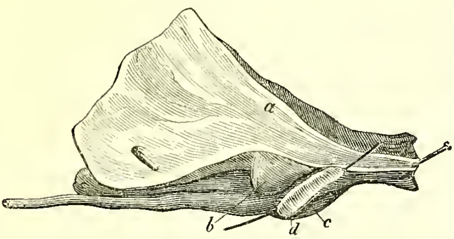
Liquor Prostaticus. — It is the office of the prostate to eliminate from the blood sent into its arteries a fluid called the liquor prostaticus. This has been examined microscopically; but in consequence of the difficulty in obtaining it in any large quantity, it has not hitherto been made the subject of chemical analysis. This fluid can be obtained after death by squeezing the gland, when it oozes through the orifices of the ducts around the veru montanum. It usually presents a turbid appearance, is of a thin milky aspect, and is somewhat unctuous to the feel. Haller found it in many cases coagulable by the addition of alcohol: it contains, according to Krause, muddy flakes, or globules, filled with minute granules, varying from $\frac{1}{900}$ to $\frac{1}{300}$ of a line in diameter. Prevost and Dumas examined the liquor prostaticus of the dog, cat, hedgehog, and rabbit: they found it to contain globules like milk-globules. Cuvier remarked in the fluid of the hedgehog, numerous ovoid and spherical vesicles, others oblong and conical in shape: many of the vesicles presented a stellate aspect, and contained a central nucleus. I have carefully examined, in many cases, the prostatic secretion of the human subject, in as fresh a state as I could possibly procure it. I have found it of a milky aspect, like a very weak mixture of milk with water. In some cases, I have seen it of a consistence more resembling cream. I consider the former state to represent the healthy fluid. Examined with the microscope, it was found to contain numerous molecules, epithelial cells, both pavement and cylindrical, in various stages of formation, and granular nuclei of about 0·0036 of a line in diameter. In by far the greater number of instances in which I have examined it, I have been rather surprised to find it give feeble but distinct signs of acidity when tested by litmus paper. I thought it not unlikely that the apparent acidity of the prostatic secretion was due to the cadaveric infiltration of urine through the tissue of the gland; but I adopted every precaution, by carefully and repeatedly washing the surface of the bladder and urethra, to obviate this source of fallacy, and the result was still the same. I have found a similar reaction in the prostatic secretion of an old man, in whom the gland was greatly hypertrophied; and where the ducts and follicles were distended with an opaque creamy-looking fluid, such as is often seen after death. The appearance of the liquor prostaticus may be, and probably is, very different after death to what it is during life. There is every reason to believe that it is secreted more clear and transparent, and it most likely owes much of its turbid appearance to the admixture of a large number of minute epithelial cells. I regret that I have nothing to offer as to its chemical constituents, as it is not possible to collect more than two or three drops at a time, a quantity too small to submit to chemical investigation. That the acidity of the

* Medical Gazette, Aug. 20. 1847.

liquor prostaticus is not incompatible with the existence of calculous concretions of the phosphatic species in the follicles of the gland, I have proved by repeated examination.

Utriculus prostaticus. Vesicula spermatica spuria. Vesica prostatica. Sinus pocularis. — At the anterior part of the most elevated portion of the veru montanum, we find an opening in the mesial line one-third or half a line broad, leading backwards to a small bag resembling a bottle in figure, of variable length and breadth: it is generally known by the name of the *sinus pocularis*, but has received

Fig. 105.



a, bladder; *b*, middle lobe of prostate; *c*, view of the left side of the utriculus prostaticus; *d*, bristle in left vas ejaculatorium.

also the designations here mentioned. In most cases in which I have examined it, it forms a canal, terminating in a blind extremity, and usually is not more than three or four lines long. I have found it an inch in length. The opening, which faces obliquely forwards, will just admit the point of a small catheter or bougie. Some surgical interest is attached to this structure, because it has been stated by writers on urethral diseases that an instrument is liable to catch in it when an attempt is made to pass it into the bladder; but I believe this very rarely happens, as the beak of the catheter is usually kept against the anterior surface of the urethra, when it is made to traverse the prostatic portion, and it is therefore carried well above this little pouch: if, however, such an accident should be suspected to have occurred, a gentle withdrawal of the instrument and depression of the handle are quite sufficient to clear the impediment referred to. But much physiological importance attaches to this sinus, for reasons which we shall presently see. Huschke describes it in the following manner: — It commences by a narrow portion, resembling a neck, which forms about half its length, behind which it swells out into a round membranous vesicle or fundus; between these two portions there is often a constriction. It penetrates the posterior surface of the prostate gland, so that the middle lobe is situated in front of its fundus. Its parietes are thinner at the fundus than at the neck, and are usually about one-fourth of a line in thickness. On either side a vas ejaculatorium is inclosed within its wall; so that, in point of fact, these ducts do not penetrate the glandular substance of the prostate. Its walls are composed of two layers, an external, fibrous and strong; an internal, of a mucous character: the latter is covered by small mucous glands, arranged closely together, with openings of about the twenty-fifth of a line in diameter. These glands resemble minute warts, each with a small opening on its apex. They cannot be confounded with the orifices of the prostatic ducts, as these always open external to this pouch, around the veru montanum. About its neck larger glandular openings are perceptible. The nature of the secretion of these glands is not known.

Great physiological interest attaches to the utriculus, from its having been supposed by anatomists to be the true representative of the uterus. Its homology with this body is evinced by its shape, and position between the two ejaculatory ducts, although the latter do not open into it, as the fallopian tubes do into the uterus; thus it resembles the latter body by its division into a neck and fundus, by its being surrounded by the prostatic ducts, as the uterus is at its orifice by the follicles there situated, and by the veru montanum forming to its orifice a prolonged inferior labium; and if, as some anatomists assert, the ejaculatory ducts occasionally open directly into the pouch, or previously unite together, the parallel is infinitely more perfect.

Morgagni has given a description and figure of the utriculus as he found it in five subjects which he examined. Ackerman also described it, and termed it *uterus cystoides*, and mentions instances described by Petit, Sue, and Maret, where it was an inch in extent. In one case mentioned by himself, it was actually larger than the prostate gland. E. H. Weber pointed out its physiological interest as a rudimentary uterus, and Huschke, has found it filled with a yellowish liquid, in which he distinctly recognised portions of cylindrical epithelium.* The best description I can find of this structure, is that by Huschke who examined it in the hare. He found it in this animal in the form of a bottle, fifteen lines in length and half an inch in breadth, extending behind the bladder. It commenced by a simple transverse fissure, from a line to a line and a half in breadth, over the veru montanum. It gradually dilated for about half an inch, and becoming contracted, it was again dilated, and terminated in a point rather to the left side. The vasa deferentia were situated by the side of the utriculus, and gradually approximating, they opened within a line of each other in the utriculus, at about a line and a half or two lines from its orifice, by two large papillary openings; so that when air was injected by one vas deferens, it not only escaped from the opening of the utriculus, but filled its cavity, and passed into the other. Huschke supposes that the utriculus in this animal always contains semen, as the existence of spermatozoa, and the appearance of the fluid indicate. In an anatomical point of view, he does not consider it at all analogous

* See note to "Huschke, in Encyclopédie Anatomique traduit de l'Allemand par A. J. L. Jourdan."

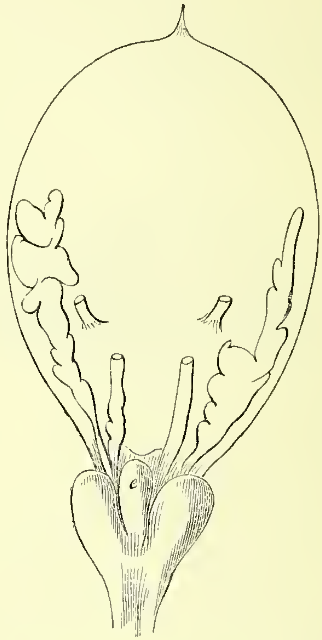
to the vesiculæ seminales of man; but in the hare as an uterus for the reception of semen, as the female uterus receives the ovule. A more minute examination of this bag strengthens this conviction. Its orifice is transverse, and represents an os tincæ in the arrangement of its labia; 2dly, there is an evident distinction in the mucous lining of its neck and fundus, it being arranged in five or six longitudinal folds, so as to form a true arbor vitæ, and seems covered with muscular fibres. The following are the deductions of Huschke:—1st, That the utriculus is a male uterus; 2dly, that it is originally a receptacle of seminal fluid; 3dly, that its development is in the inverse ratio of the development of the vesiculæ seminales and prostate gland in man; 4thly, that it is a vestige of a structure existing in the fœtus, and in man is really of no use whatever.

Cuvier has described a long membranous canal with a spherical extremity, situated between the two vasa deferentia in the solipeds. This long bag opens on to the urethra, in front of the common orifices of the vasa deferentia and vesiculæ seminales, rather to the left side. A fluid of the consistency of honey can be squeezed out of it. This is evidently the utriculus.

In an interesting case of hypospadias, a case peculiarly favourable for the investigation, Professor Theile, of Berne, most carefully examined the utriculus, and described its anatomical relations. I take the following account of this examination from the first number of the "British and Foreign Medico-Chirurgical Review:"—"The scrotum contained two testicles; the vasa deferentia, vesiculæ seminales, and prostate gland were present. The latter was fourteen lines long, eight and a-half thick, and sixteen broad. Theile found a canal originating in the usual opening on the utriculus, run backwards for an inch and a half, ending in a cul-de-sac four lines in diameter, and placed between the two vasa deferentia; this canal (vesica prostatica), with the exception of its anterior part, did not lie within the prostate, but below or behind this gland. Besides this structure, a small, oval, glandular body, five lines long, four broad, and two thick, was found behind, lying between the vesica prostatica and the prostate itself; it did not appear that this substance was continuous with the substance of the prostate, although this continuity might have existed and escaped detection. Examined by the microscope, this body presented an aggregation of cells and vesicles, which were much more easily seen in it than in the proper prostate. Theile regards this body, lying closely upon the vesica prostatica, as a middle lobe of the prostate. In order to ascertain the relation of the ductus ejaculatorius with the vesicle, a wax injection was thrown into the lower part of the vas deferens. On a careful examination, it was found that the ejaculatory duct did not open into the utriculus, but was only closely applied to its lateral wall, and then penetrated into the urethra in the usual place." In this case the membranous portion of the urethra opened into a normal bulbous portion.

Professor Theile also gives an account of another case of hypospadias, "dissected by

Fig. 106.



e, utriculus prostaticus, from Müller's Archiv.

the elder Sœmmerring, in which the urethra and scrotum were fissured, the testicles remaining in the abdomen. Between the glands and the anus two openings were found, separated by a partition of about one line in breadth. That next the penis was the orifice of the urethra; the latter led into a canal, into which a quill could be passed. It was an inch and a half long, and when inflated it was nearly as large as the little finger, and was situated between the bladder and rectum, but nearer to the former. Sœmmerring laid open the canal towards the rectum, and it appeared like 'an alveus communis,' into which the vesiculæ seminales opened. When quicksilver was injected into the vasa deferentia, it ran partly into the vesiculæ seminales, but partly into this pouch." "The existence in the male of a central sac or canal, occupying precisely the same relation to the orificium urethræ, the bladder, and the rectum, as the vagina in the female, is particularly elucidative; and, among other facts, for which we are indebted to embryological research, further corroborates the conclusion of the most scientific anatomists of the present day, that every variety of so-called hermaphroditical malformation is referrible to an abnormal condition, either of the male or of the female organs, existing singly, and but rarely conjoined in the same individual."

With these facts before us, there is no necessity to resort to the mechanical idea of the gradual distension of the prostate gland and vesiculæ seminales to account for the existence of a rudimentary uterus in those cases of hermaphrodism where the subject is unquestionably male, with an increase in the development of the utriculus beyond its natural condition. I would also venture to suggest, that what Mr. Hunter has delineated as the uterus, in the representation he has given of the dissection "of Mr. Wright's free-martin, which are more the parts of a bull than those of a cow," is really a preternaturally large utriculus prostaticus. I have given a side view of the interior of the utriculus, in a case which I examined myself; in this instance it extended obliquely downwards and backwards, beneath the third lobe of the prostate, for the distance of about half an inch, and was slightly enlarged at its fundus. (See *fig.* 104.)

The development of the prostate and vesicula prostatica.—There is no department of embryological research of higher interest than that relating to the development of the genito-urinary system. A minute inquiry into this subject, and a careful observation of the phenomena attending it, can afford the only means of obtaining a satisfactory clue to the comprehension of that remarkable structure just described. By no other means is it possible to ascertain the natural relation of the utriculus prostaticus.

I shall limit the inquiry here to the manner in which the utriculus and prostate gland are supposed to be formed.

At an early period of fœtal existence the allantoid sac, which was continuous with the urinary bladder, becomes shut off entirely from that viscus, and the only remains of its original communication is the obliterated urachus. As the bladder at its inferior fundus communicates with the intestine, thus forming with it one common cavity, it may fairly be said that the human subject really is at this period possessed of a cloaca. In the mammiferous class generally the urinary bladder very soon separates from the intestine, and has a separate opening externally in front of the anal aperture. There are different opinions as to how this is actually accomplished; but there is no necessity to discuss the question here. In this separation of the bladder from the rectum, the evidence of the existence of a cloaca disappears, and a cavity, or space, or canal is left common to the bladder and genital organs; this is termed the *sinus uro-genitalis*, or the *canalis uro-genitalis*. This afterwards, in the male, is represented by the neck of the bladder and beginning of the urethra, and communicates with the external organs. In the monotremata the uro-genital canal is persistent. The sinus uro-genitalis receives the terminations of the excretory ducts of the Woolfian bodies, the ureters, the vasa deferentia in the male, and the fallopian tubes in the female. In the female the vagina and uterus are both developed by extension and division of this canal,—the vagina having in front of it the urethra; and as development advances, the last portion of the sinus uro-genitalis is represented by the vestibulum, and is common to the urethra and the vagina. According to Valentin, in the male the vasa deferentia at first open together in the mesial portion of the uro-genital canal; in the female the same is observed in respect to the fallopian tubes. Rathke states that at a later period a small conical crimpling of the uro-genital sinus occurs near the openings of the vasa deferentia, and that from this the vesiculæ seminales are developed, which communicate with the vasa deferentia, and, indirectly, with the sinus, or with the urethra itself. A separation takes place between the two vasa deferentia, when each vas deferens, uniting with a corresponding vesicule, opens separately into the urethra. In the interval between the terminations of the vasa deferentia we find the remains of the uro-genital sinus, which eventually becomes the *utriculus*, or *vesicula prostatica*, or *sinus pocularis*.

Bischoff thinks that the prostate gland commences by a simple thickening of the vasa deferentia near their termination. It is most probably further developed in the same manner as the glandular system generally. He agrees with Rathke in the opinion that there exists a septum between the two sides at this portion of the urethra, the vestiges of which are represented by the veru montanum.

To complete the analogy between the utriculus and the female uterus, the vasa ejaculatoria ought to terminate beneath, or rather within the utriculus, as the fallopian tubes do in the uterus; and this is said really to happen occasionally. Morgagni mentions two instances of this. I have found it myself, but it is rare; yet the fact of even its occurrence now and then adds all we require to complete the evidence in favour of the analogy between these two apparently dissimilar structures. Presuming all that has been stated to be true, we need not tax our ingenuity further, in endeavouring to assign a use to this heretofore obscure structure the *sinus pocularis.*

The prostate, up to the period of the full development of the organs of generation, is of small size. In the early periods of fœtal existence it is composed of two lateral lobes, which coalescing at the fourth or fifth month, give rise to the isthmus and third lobe.* It is rounder in the child, is situated vertically, and is said to be occasionally just reached by the peritonæum. As we advance in life it becomes firmer in texture and yellowish in colour. Mercier says that in the child the anterior part of the gland exceeds the posterior in thickness; in other words, that the prostatic ring encircling the urethra is thicker above than below.

Function of the prostrate gland. — It is the office of the prostate to secrete a bland and

* I do not consider the isthmus and third lobe as synonymous expressions, and would limit the former term to that portion of the gland which connects the lateral lobes beneath the urethra.

somewhat viscid fluid, which is poured into the urethra at the commencement of its course, at that point where the secretion of the testes and vesiculæ seminales are received into the canal. It is well known that the secretion of the prostate is increased in quantity under states of venereal excitement; I have, however, some doubts as to whether the secretion effused under such circumstances is wholly prostatic: I cannot help thinking that some of it at least is due to the glands of Cowper and the follicles of the urethra generally; but, be this as it may, there can be no doubt that the largest quantity of the prostatic fluid is poured into the urethra at the moment of, or prior to, the venereal orgasm; at least we are justified in drawing this inference from observations made on these parts in animals killed during, or immediately after, the completion of the act of copulation.

That the prostatic fluid is subservient to the generative function, may be deduced from these circumstances; and this is further established by the fact mentioned by Hunter, that the gland is liable to changes at certain seasons, and that in the mole, in winter, the prostate is scarcely discernible, whilst in the spring it becomes of large size, and filled with fluid. We are not aware whether this is the case universally in the animal kingdom. How does the prostatic fluid aid the function of generation?

An old opinion assigns to these accessory glands the office of perfecting and increasing the bulk of the seminal secretion, so that the urethra may be more fully distended by it, and its muscles may be enabled to act more completely in forcibly injecting its contents into the vagina. This idea is, in my mind, rather too mechanical, although it may be advanced in its favour, that these accessory glands are found in all animals, where they exist, to empty themselves into those dilated portions of the urethra, in which the seminal secretion is supposed to accumulate prior to its expulsion. It has been thought by some that the prostatic secretion is useful in diluting the semen, so as to increase its bulk, not merely for the more perfect distension of the urethra, but that it may ensure the more easy transmission of this secretion into the female vagina, and thus favour its contact with, and impregnation of, the ovum. As to its defending the orifices of the ejaculatory ducts from the presumed acrimony of the urine, I cannot attach any importance whatever to this notion; the gland is essentially a sexual organ, and its use must, in some manner or another, be connected with the excretion of the seminal fluid, either in the manner just mentioned, or in lubricating the surface of the urethra, so as to facilitate the onward passage of this fluid. The very structure of the prostate, which is of the simple follicular character, favours the latter notion. Its position at the commencement of the urethra leads to the same conclusion. It is probable that its secretion is poured into the urethra prior to the escape of the seminal fluid into the canal; and it is quite evident that no large glandular masses could have been conveniently placed along the urethra in any other situation; for however much they vary in number and size, in the various orders of animals, their position near the beginning of the urethra is constant.

The prostate gland, with Cowper's glands and the vesiculæ seminales, must be regarded as accessory rather than as organs essential to the generative function. That it is not essential in man, is rendered probable by the persistence of the procreative faculty in many cases of extensive disease of this organ.

In connection with this obscure and difficult subject, I think the fact of the prostatic secretion being naturally, as I believe, acid, is a circumstance of some interest. The secretion of the testes is well known to be alkaline, and has a strong tendency to coagulate or become inspissated. Is it not probable that the reaction of the prostatic on the seminal fluid may be of use in the maintenance of the fluidity of the latter? The idea is somewhat confirmed by the fact, that in women the acid secretion of the vagina prevents the coagulation of the menstrual blood, and thus favours its discharge. This has been proved by Mr. Whitehead, who found that, if the menstrual fluid was received directly from the os uteri into a speculum, it coagulated like ordinary blood.*

Morbid Anatomy. — *Hypertrophy.* — In advancing years, when all other structures in the body begin to show evidence of a failing nutrition, and are atrophied or wasted by interstitial absorption, the prostate gland, on the contrary, very frequently becomes the subject of a remarkable increase in size. This is so common after the age of fifty, that an enlarged prostate may be almost regarded as one of the necessary contingencies of advanced age. It is not, however, exclusively in the old person that this takes place; it sometimes happens at a much earlier period of life; nay, a case is mentioned by Sir Astley Cooper of a boy whose prostate was found, on dissection, of very large size; but it is not improbable that this remarkable enlargement depended on strumous deposit in the gland. In considering this subject, it is important to distinguish between this affection of the prostate and the simple engorgement consequent on acute or chronic inflammation; these latter conditions occur more frequently between twenty and forty years of age, and depend on stricture of the urethra, or the mal-treatment of severe gonorrhœa.

Hypertrophy of the prostate is so insidious in its mode of invasion, that the only indications of its occurrence are evinced by the mechanical impediment to the free discharge of the urine, in consequence of the increased size of the gland. No pain, no uneasiness is felt before the prostate has obtained a considerable volume, after which, symptoms of a most distressing character set in, and continue, with more or less severity, to the termination of

* On the Causes of Abortion and Sterility, &c., by James Whitehead, 1847.

the patient's existenee. It would be out of place here to enter into the signs which characterise the progress of this disease. I must confine my observations to the state of the gland itself, to the effect produced upon the adjacent structures by its enlargement, and to its cause.

In senile hypertrophy, the gland becomes enlarged in all its dimensions; it expands laterally, extends downwards towards the rectum, so as to be readily felt, forming a considerable tumour in this situation, and upwards behind the symphysis pubis, so that in a thin person, with the hand firmly pressed upon the hypogastric region, the surgeon can, in some cases, feel it distinctly. Its outer surface is smooth and round, or occasionally irregular and nodulated: the two lateral lobes expanding universally, are pressed together, so as to become flattened at their opposed surfaces; if one increases particularly at one part, as is often the case, there is a corresponding indentation in the other, and thus the direct course of the urethra is altered, and the canal is twisted in various directions. The disease is not usually confined to its lateral lobes; for the third lobe frequently participates in the enlargement. This may happen to a great extent, in some measure, independently of the increase in size of the lateral lobes; but usually, where the middle lobe is affected, the lateral lobes are enlarged, although the converse of this condition is not so invariable. The middle lobe sometimes forms a simple pyramidal elevation at the urethral orifice; sometimes a large pendulous or valvular tumour, occasionally rising upwards from the posterior part of the prostate in the mesial line direct, frequently inclining to one side. It has been known to attain the size of a small orange; and where it has increased to such an extent, it must of necessity happen that the base of the tumour is the smallest part of it. Whatever form of enlargement the middle lobe assumes, the tumour always projects towards the bladder: it is frequently knotty or lobulated on the surface. In its increase, the third lobe draws up the prostatic portion of the urethra, and elongates the veru montanum. Very great interest has attached to this condition of the middle lobe, in a surgical point of view, since Sir Everard Home particularly directed the attention of surgeons to Mr. Hunter's observations upon it, who states "that it sometimes increases so much, as to form a tumour projecting into the cavity of the bladder some inches." The disease of this part of the gland had not escaped the observation of Morgagni, although he did not attach much importance to it: it was also known to Valsalva.

Hypertrophy of the prostate is frequently attended with general induration, so that when cut into, it almost resembles cartilage. This has obviously given rise to the term *scirrhous prostate*, as applied by the older surgeons to the disease in question. In other instanees, it feels softer than natural. The capsule becomes gradually attenuated by distension, and the direction of the tumour is always towards the part where there is least resistance.

It has been very commonly asserted that the left lobe is more frequently hypertrophied than the right. The observation originated with Sir Everard Home. I cannot deny the truth of the assertion; but it is divested of any practical importance, as it is well known that the right lobe is in very many cases the larger of the two. However, the fact that the two are very frequently unequally enlarged, ought to be impressed upon the mind of the surgeon, as he may expect that the course of the urethra will deviate to either side, and (in the introduction of the catheter) in cases of retention, from enlarged prostate, he must direct his instrument accordingly.

The enormous increase of size which the prostate attains, produces serious inconvenience to the parts adjacent. Thus, independent of the effect on the nerves of the pelvis, as indicated by pains in the loins, sacrum, groins, and down the thighs, its influence is most sensibly perceived in the altered state of the urethra, in the bladder, and the rectum. By the enlargement of the prostate, the urethra is increased in length — a fact well known to practical surgeons. This actual elongation takes place only in the prostatic portion of the canal; the diameter of the urethra, so far from being diminished, is really increased; but the part surrounded by the gland is altered in shape; for, whereas in the natural state the prostatic sinus is longer in a transverse than in a vertical direction, it is now quite the reverse: its sides are also approximated by the coaptation of the lateral lobes; and if any unequal projection of either lobe exists, it takes a tortuous course to reach the bladder, or reaches it by two channels, one on each side of the middle lobe; besides which, the urethral orifice into the bladder is more or less blocked up by the projection of the middle lobe, or is raised higher than natural, the prostatic part of the canal forming a sickle-like curve, the convexity of which is downwards. The prostatic sinus is occasionally dilated to such an extent, as to be capable of holding two ounces or more of urine. The veru montanum is placed at a greater distance than natural from the bladder. The bladder becomes either preternaturally dilated, or contracted to a very small size; these two opposite conditions probably depending on the greater or less irritabili·· of the viscus; sometimes it is sacculated; its muscular coat is thickened, and its mucous lining becomes the seat of acute or chronic inflammation, with all its accompanying pathological changes. So also the ureter and even the kidneys themselves are frequently diseased in the advanced stages of this affection. When the third lobe is much enlarged, it throws the neck of the bladder forwards, and increases the depth of the inferior fundus to such a degree, as to cause the lodgment of calculi in its cavity. In one respect, this circumstance is attended with some advantage, inasmuch as it lulls the symptoms of stone, by preventing

the calculus from coming in contact with the sensitive neck of the bladder. But an obvious inconvenience arises in other cases from the difficulty of seizing calculi under such circumstances, in the operation of lithotrity; and after a calculus is broken up, it prevents the escape of the fragments, and thus favours the recurrence of the disease.

Its influence on the rectum is felt in the flattening of its cavity from before backwards, and by its projection it causes the rectum to rise up on either side of it. Hæmorrhoids and prolapsus ani are by no means unfrequent attendants on enlargement of the prostate.

On examining with the microscope sections of an hypertrophied prostate with Mr. Quekett, I found numerous crystals in its ducts, which disappeared on adding dilute muriatic acid.

Atrophy. — The prostate is liable to atrophy, but the disease is rare. I have met with it myself occasionally in very old persons. When the gland is altogether diminished in size it is usually more consolidated in its texture. It is, however, liable to another form of atrophy (eccentric atrophy), by which I mean a thinning of its tissue generally, and its conversion into one or more cysts, in consequence of continued pressure exerted by the increase in size of calculous concretions in its follicles. "Cases sometimes occur, in which the whole of one lobe, or even the entire organ, is converted into a thin fibrous capsule, the proper substance of the gland being almost wasted."—(Crosse's Pathology.) In those cases the ducts of the prostate are usually increased in size, so as to arrest the progress of the catheter. It generally occurs in connection with urinary calculi, or long-standing stricture. Dr. Baillie met with one instance of atrophied prostate; it occurred in a case of ectropium of the urinary bladder, and malformation of the organs of generation; the utriculus prostaticus was larger than natural.

Inflammation. — Inflammation, acute or chronic, not unfrequently attacks the prostate, leading to increase of size, and suppuration of the gland. It is very commonly the result of suppressed gonorrhœal discharge, and follows the employment of copaiba, cubebs, and powerfully stimulating injections. The signs of this condition are easily understood. With careful and somewhat active treatment by leeches, cupping in the perinæum, warm fomentations, &c., the disease terminates in resolution; but permanent enlargement or suppuration are the too frequent consequences of inflamed prostate. An irritable state, characterised by an uneasy sensation referred usually to the end of the penis, and attended by an increase in the secretion of the gland, which can be drawn out in threads, with a frequent desire of making water, indicates an inflamed condition of the prostatic ducts. The discharge is occasionally puriform in appearance.

Abscess. — If the inflammation be unsubdued, suppuration often occurs. The whole tissue of the gland is, in some instances, infiltrated with pus; in others a single abscess, of large size, or numerous small abscesses occupy one or both lobes of the prostate. Sir Benjamin Brodie relates an instance of an old man, the subject of abscess of the prostate, containing at least half a pint of pus, which escaped through the catheter, after the urine had been drawn off. Many similar instances are recorded. These large collections are generally the result of an attack of acute inflammation on an already enlarged prostate. Smaller purulent deposits are met with in various parts of the gland; so that when after death the pus is washed away, the prostate is found riddled with holes. Such deposits are not uncommonly associated with suppuration of the vesiculæ and the adjacent structures; and are frequently consequent on intense sexual excitement and onanism. Lallemand gives many instances of this, and relates one in particular, where the urethral membrane was perforated by numerous apertures, through which the pus escaped, so as to present a sieve-like appearance, which he compares to the cribriform lamella of the ethmoid bone. Mr. Curling* mentions a similar case of a young man excessively addicted to onanism, and who died with symptoms of cerebral congestion. The prostate was converted into a multilocular cavity, and the urethra was perforated by numerous large apertures. These openings are the orifices of the prostatic ducts preternaturally enlarged, suppuration most probably commencing in the minute follicles of the gland. A secretion of a puriform fluid often takes place from the prostatic ducts in cases of severe attacks of gonorrhœa, and small abscesses give way one by one.

Abscesses of the prostate open in various directions. Not unfrequently they burst into the bladder on the introduction of the catheter. Sometimes they open into the urethra on the side of the veru montanum; or they make their way forward to the perinæum, and opening externally terminate in the formation of perinæal fistulæ. Occasionally they open at once into the rectum; or they may burst into the adjacent cellular membrane, and even extend to the penis and scrotum.

Ulceration.—This mode of termination of an inflamed prostate is rare. It is one of the most distressing consequences of inflammation, and is only found in cases of hypertrophy of the prostate in old age. It may arise spontaneously, or it may be the consequence of the rude introduction of the catheter. It is invariably attended with most severe symptoms, and is generally indicated during life by the mixture of blood with the urine. The mucous membrane of the bladder adjacent is in a state of high inflammation. Ulceration may exist in various degrees, from simple erosion, as after passing a catheter, to a deep ulcer with indurated edges. In one case, related by Sir Benjamin Brodie, the prostate was found ten or twelve times its natural size, making a large circular projection into the bladder, round the internal orifice of the urethra. Nearly the whole of this portion was

* Curling, on Diseases of the Testicle.

superficially ulcerated, and in some places the ulcerated surface was incrusted with a thin layer of coagulated lymph.

Simple enlargement of the prostate is another consequence of common inflammation. It is one of the not unfrequent sequelæ of repeated and neglected attacks of gonorrhœa. It is generally accompanied with induration, and is confined to the lateral lobes, rarely implicating the middle lobe. This condition is occasionally dependent on the irritation or stricture of the urethra, and subsides on the cure of the latter disease.

Tubercles. — The deposit of scrofulous tubercles in the prostate is rare. When this happens it is generally found to co-exist with similar deposition in the testicles, vesiculæ seminales, and the adjacent lymphatic glands, and is associated with tubercles in the lungs. It occurs occasionally in the form of one large mass, occupying a large portion of the gland, and causing an increase in its size, or many small distinct depositions are found in various situations. Scrofulous tubercles of the prostate undergo the same progressive disintegration as in other parts, and terminate in abscesses, which take a similar course and direction as common abscesses. I have seen the whole tissue of the gland broken down by the gradual softening of scrofulous tubercles. Mr. Cross, of Cincinnati, met with one instance of this disease; it was in a young man who died in the Cincinnati Hospital of psoas abscess. There were six or eight small masses of a pale yellowish colour, and of a soft curdy consistence, scattered through different parts of the gland, which was considerably reduced in size; he thinks they are originally formed in the follicles of the gland. Lallemand also mentions a case in which thirty small abscesses, and the same number of crude tubercles were found in the prostate. There were similar deposits in the kidneys.

Cancer. — Cancer in any form is extremely rare in the prostate. Carswell regards it as a not uncommon cause of hæmorrhage from the urethra, whilst Cruveilhier says that he has never seen an instance of it.—(Walshe on Cancer.) The encephaloid form is that which most commonly attacks this gland; and, according to Walshe, in M. Tanchon's tables, out of 8289 fatal cases of cancer, in five death occurred from the disease in the prostate. Rokitanski regards the affection as very rare, and makes allusion only to the encephaloid variety. When the disease attacks the prostate, the gland becomes increased in size. It has been found by Mercier of the size of an ostrich's egg, "and was attended with effusion of blood into both lobes, communicating with each other and with the urethra by means of false passages." In a boy, five years old, Mr. Stafford found the prostate of a globular form, and as bulky as the largest walnut; the middle lobe was nearly as large as a small hazel nut. — (Walshe.) By the same author, a case is recorded from Langstaff of an encephaloid growth as big as an orange, which sprang principally from the middle lobe. Cancer of the prostate, as it advances, generally makes its way towards the bladder, and thus forms a bleeding mass in the cavity of that viscus, occasionally filling it up completely, and giving rise to a distinct hypogastric tumour, which I have known mistaken for a bladder over-distended with urine, the true nature of which was not suspected until after the introduction of the catheter. The cancerous mass at its base was surrounded with a distinct border of ulceration, so characteristic of cancerous tumours, when they have made their way into cavities lined with mucous membrane.

The secretion of urine is frequently, under this condition, in a great measure suspended. I have known one case where the bladder was tapped above the pubis, under the idea that it was filled with urine; but little or no urine escaped, and after death the bladder was found filled with a cancerous tumour originating in the prostate; and no doubt many such instances have happened. It is a mistake of no very serious consequence, but might be avoided if a careful examination of symptoms were instituted. If an elastic catheter were gently introduced into the bladder, it would be found to give the impression as if it entered a spongy substance, little urine would escape, and that tinged with blood and mixed with shreds of cerebriform matter: if doubt still existed, a microscopical examination of the substance voided would, I apprehend, set the matter at rest. The introduction of the finger per rectum will assist the diagnosis.

True scirrhus of the prostate is extremely rare. Mr. Travers and Sir Benjamin Brodie both allude to supposed cases of this disease, and from the narration there can be little doubt of their genuineness. The former surgeon examined one case after death, and described the gland as occupied by a tumour, having all the character of scirrhus; and the latter mentions an instance "where the prostate was found much enlarged, and of a stony hardness."—(Walshe.)

Fibrous tumours, according to Rokitanski, are frequently found in the prostate. They are of a size varying from that of a pea to that of a hazel nut, are round or oval, causing, when seated at the peripheral portion of the gland, knotty protuberances on its surface. They are always attended with distinct hypertrophy of the gland. This eminent pathologist attaches great interest to them, on account of their similarity to fibrous tumours of the uterus. They are of very frequent occurrence; and in many cases of the enlarged prostate of old men that I have had an opportunity of examining, I found them readily distinguishable on section. This subject has been alluded to before, in the account of the morbid anatomy of the enlarged prostate.

Cystic Prostate. — The prostate, like the kidney, is occasionally the seat of cystic disease. It is characterised by the formation of cysts in various parts of the gland. It is extremely rare. There is an excellent example of it in the Museum of the College of Surgeons. The gland was hypertrophied, and

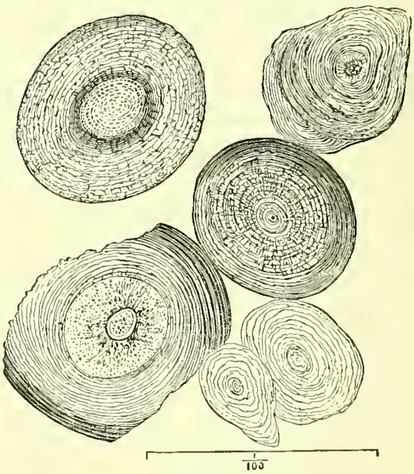
on section was found studded here and there with cysts containing fluid. These are, in all probability, dilated and closed follicles; and in this respect they bear a strong analogy to the cysts of the kidney, which are found to be dilated uriniferous tubes.

In the situation of the uvula vesicæ, the fold of mucous membrane is occasionally thrown up, so as to form a remarkable projection or bar at the neck of the bladder. Mr. Guthrie especially directed the attention of surgeons to this, but it has been met with often by others, and there is a good representation of it in Baillie's Morbid Anatomy. No doubt it has often been confounded with supposed enlargement of the middle lobe of the prostate, with which it is often combined, but of which, in many cases, it is wholly independent. In a surgical point of view it is of very great interest. The bar in question, in its most simple form, consists simply of a double fold of mucous membrane, raised at right angles from the bladder; in other cases, there is found between the layers of mucous membrane a quantity of a substance of an intermixture of elastie and organic muscular tissue, similar to what is found in the neck of the bladder in the normal condition; whilst in other instances, apparently in the more advanced stages of the disease, the middle lobe of the prostate, considerably hypertrophied, is found as if it had forced its way between the mucous layers, and thus carried the fold with it; in the latter condition, it will be found in the form of two wing-like processes, one on either side, connecting the middle lobe to the side of the bladder.

The disease is necessarily attended with difficult micturition, and leads to retention of urine. The diagnosis between retention from this cause and from enlarged third lobe is difficult, but practically it is not unimportant, as Mr. Guthrie thinks it may be cured. In the rough introduction of the catheter or bougie, the bar is sometimes perforated. This surgeon found in one case as many as fifty calculi behind this projection. It leads, if neglected, to similar changes in the bladder, as are found in cases of enlarged prostate.

Prostatic Concretions. — The formation of calculous concretions in the minute follicles of the gland are not by any means of unfrequent occurrence. They are not to be confounded with calculi of larger size, which have been long recognised by pathologists, and have been especially alluded to and described by Baillie, Woollaston, Cruveilhier, and Prout. They have very recently been examined by Mr. John Quekett and Dr. C. H. Jones, the latter of whom has published a paper on the subject in the first number of the Transactions of the Pathological Society, and in the Medical Gazette of August 20th, 1847. The following is the result of the microscopical observations on this subject:—The calculi are found in great numbers in the follicles of the gland, presenting sometimes a deep yellow or red colour; occasionally they are pale and colourless, remarkably small, and scarcely to be distinguished from the tissue in which they are imbedded. Dr. Jones describes their mode of formation thus: "They arise in a large oval vesicle, of a single wall of homogeneous membrane. This is occupied by a colourless finely-mottled substance, in the centre of which a nuclear corpuscle sometimes occurs. Their mean diameter is about $\frac{1}{1000}$th of an inch. In those of larger size, the envelope is still seen, but the contained amorphous matter is beginning to be arranged in layers concentric to the envelope. In the further stage, the vesicles measure $\frac{1}{200}$th of an inch or more, showing concentric layers, which are more developed on one side than on another, like so many repetitions of the original envelope, the intervals between the layers being occupied by a finely-mottled deep-yellow or red substance. There is a central cavity corresponding with the external contour in its form, which is triangular, with rounded angles or quadrilateral. From this normal appearance, these bodies present numerous variations in form and internal arrangement, and appear to occupy an intermediate position between organic growths and inorganic concretions: to the former, by their vesicular origin and by their growth, which chiefly appears to take place by the dilatation of the vesicle and successive depositions in its interior; to the latter, by their shape, their tendency to become infiltrated with earthy matter, and to pass into the condition of a dead amorphous mass of a deep yellow red, even almost black. The chemical composition varies probably with their different stages of development, at first consisting of little else but animal matter, then acquiring, especially when in a state of degeneration, calcareous salts, stated by Dr. Prout to be phosphate, with a little carbonate of lime. The colouring matter is unaffected by ether, liquor potassæ, and muriatic acid."

Fig. 107.



Prostatic concretions.

These minute concretions in the follicles and tubes of the prostate have been investi-

gated by Mr. Quekett, who, on submitting sections of the gland either in a healthy or diseased condition, to microscopical examination, has met with them so frequently, that they would seem to be a part of the natural constituents of the gland or its secretion. He describes them as commencing by a deposit of earthy matter in the secreting cells of the gland; they increase in size either by aggregation, or by deposition in the form of concentric layers; in the former case they mould themselves to the follicles, in the latter they present the appearance of an ordinary lithic acid calculus on section. Where many cells were together, the parietes of the cells in contact are destroyed; so that by adding dilute muriatic acid, and thus dissolving the earthy matter, a multilocular cavity remains. In consequence of the manner in which they mould themselves to the follicles, they frequently present an appearance externally like mulberry calculi.*

The opinion of Prout that the deposition of earthy salts is the result of a deranged action in a mucous membrane appears thus fully borne out. In a case which I recently examined with Mr. Quekett the concretions were exceedingly numerous; and this was especially remarkable in the middle lobe of the prostate. The gland had been removed from a young man who had died of phthisis, and was of the natural size. The middle lobe was much firmer than either lateral lobe They are soluble in acetic acid by the aid of heat.

Prostatic Calculi.—It is most probable that these concretions undergo an early solution; thus yielding up their granular or amorphous contents to form a part of the secretion of the gland. This is the opinion of Dr. Jones. But if they are not removed in this manner they become the nuclei of prostatic calculi.

Prostatic calculi are thus formed in the gland, occasionally in immense numbers; they are generally rounded in form, and from their pearly semi-transparent appearance, Dr. Wollaston compared them to grains of pearl barley. They become covered with a brownish coating from a deposit from the natural secretion of the gland. Continuing to increase in size, they come in contact with one another, and at the points of contact are as it were articulated together. They are smooth upon the surface, and often resemble porcelain from the high polish they obtain. As they increase still further in size they cause absorption of the surrounding glandular substance, and thus convert the gland into a multilocular bag, in which as many as fifty or sixty calculi have been seen. In this condition, if the finger is passed per anum, the prostate gives the feel of a bag of marbles. Sometimes there is only a single large cavity in one lobe filled with a single calculus. The smaller stones often escape into the bladder through the dilated ducts, and are readily extracted by the urethral forceps. When divided they exhibit a radiated and laminated structure; or they are compact.

* See Guy on Cause and Treatment of Stricture of the Urethra, and Diseases of the Prostate Gland. 1845.

From the analysis which has been made of the prostatic calculi in the College of Surgeons, it appears that the relative proportion of phosphoric acid and lime in all the varieties of these calculi appears to vary considerably, although they may, in all probability, be reduced to two salts, — the neutral phosphate of lime, or the diphosphate, which exists in those varieties that are partially fusible before the blowpipe, and which generally exhibit a crystalline structure; and the basic phosphate of lime which is completely infusible by the mouth of the blowpipe. In estimating the fusibility of these compounds, care must be taken that none of the triple phosphate is present.* When they pass into the bladder, they excite irritation of its mucous surface, and become coated with the triple phosphate; or if a large stone remains in the prostatic portion of the urethra, it may cause a deposit of lithic acid on its surface from the urine which is continually passing over it. A single calculus sometimes extends from the prostate into the membranous part of the urethra, which becomes much dilated. In these cases the calculus has usually an elongated, somewhat conical figure, and consists of two or three separate portions, which are closely adapted to each other, and have polished articulating surfaces at the point of contact. The rounded extremity of one calculus is often received into a corresponding concavity of another. These calculi almost always contain a larger portion of phosphate and carbonate of lime, than those found in any other situation. When the prostate is completely disorganised and converted into a mere cyst, the calculi found in its cavity are of the fusible character, or contain more or less of the triple phosphates.

It sometimes happens that the phosphates are secreted by the prostate in immense quantities, and are excreted with the urine, giving it a milky aspect. This may be confounded with a similar deposit from the urine itself, but it is generally accompanied by symptoms of irritation of the prostate gland and neck of the bladder — as discharge from the urethra; hence the diagnosis is not difficult.

" Vogel, in his pathological anatomy of the human body, has given an account of these prostatic calculi: he described them of small size, not larger than a pin's head, and usually of a brownish, reddish-brown, or yellowish-brown colour, presenting a crystalline or laminated arrangement, with a polyhedric or facetted surface. He says that they are formed by a precipitate of phosphate of lime.

" Lassaigne has given an analysis of the quantitative composition of these concretions. Thus in 100 parts there are contained

Basic phosphate of lime . .	84·5
Carbonate of lime . . .	0·5
Animal matter (mucus, &c.) .	15·0

It is presumed that they are formed by a deposition of these salts when existing in excess in the prostatic secretion. Similar concre-

* Catalogue of Calculi contained in the Museum of the Royal College of Surgeons in London, 1842.

tions are occasionally met with in the vesiculæ seminales and vasa deferentia; but, according to Peschier, their analysis differs slightly from prostatic concretions. Thus he found in 100 parts

Phosphate of lime . . .	90·0
Carbonate of lime . . .	2·0
Animal matter	1·0"*

Comparative Anatomy. — Assuming the prostate to be represented by a glandular structure placed at or near the termination of the vas deferens, it is found in many of the invertebrate animals. As a general rule, it is only discovered in those possessed of an intromittent organ; this, however is not invariable. In the medicinal leech, among the annellata, according to Owen and Brandt, the two vasa deferentia and the two sacculated vesiculæ seminales send their ducts to a common prostatic body, from which the penis is continued. "In the centipede, among myriapoda, a minute efferent tube is continued from both ends of each testis, which tubes unite with those of the adjoining organ, and ultimately form a single vas deferens, which, having received the ducts of three pairs of small prostatic glands, terminate in the cloaca. In the male *aphis* there is a long pyriform vesicular gland attached to each lateral vas deferens, and in many insects representatives of prostatic glands communicate with the ductus ejaculatorius." † In the slug, among gasteropoda, the vas deferens is joined by the short and simple duct of a small prostatic sac; and this is the case in the common snail, in whom the duct is, however, longer. In the cephalopoda, as in the *octopus*, "the anterior extremity of the contractile vesicula, into which the efferent duct opens, communicates with a wide, bent, cœcal tube (prostate), with thick glandular parietes, and having the form of a simple pouch in the *sepia*. The prostate in the *sepiola* communicates by a long and slender duct with the vesiculæ seminales." †

In *mammalia*, two varieties of prostate are found, distinguishable as to structure from each other: one, the cellular, in which small cells open into a central cavity, from which a large duct arises; and the other, the follicular, composed, as Müller says, "of large intestinules, or larger ramose follicles."

In the *ape* tribe, the form of the prostate is larger from above downwards than from before backwards, and surrounds the urethra in the form of a crescent. In position, size, and structure, it resembles that of man. In the *mandril* some accessory lobes are found. The prostate of the *makis* sends off two prolongations, which surround the excretory ducts of the vesiculæ seminales.

In the *tarsier*, there are two distinct glands, placed in front of the vesiculæ seminales, on the side of the urethra.

The *galeopitheci* have a single prostate of large size, surrounding the base of the vesiculæ.

In the *roussette*, the prostate is simple, and surrounds a large portion of the circumference of the urethra.

In the *dormouse*, it surrounds the whole circumference of the urethra, and is composed of a number of lobules.

In the *hedgehog*, the prostates are four in number, and they belong to the tubular class. The superior prostates are the larger, and are composed of long flexuous tubes, united into lobules, which form lobes, whose tubes reunite to form a single excretory duct, which pierces the superior surface of the urethra. They are attached by processes of the peritonæum to the abdominal muscles. — (Hunter.) Two other bundles of smaller size, and of a rounded form, represent the inferior prostates. They are composed of smaller tubes, which separating in the form of a fan, pass towards the circumference of the gland, and terminate in cœcal ends. The excretory ducts open one on either side of the veru montanum. The tubes are composed of membranes of extreme delicacy.

In the *mole*, the prostate is single, and is formed of membranous tubes folded upon themselves. At the period of heat, it increases so enormously as to exceed the urinary bladder in size; it is placed around the urethra in front of the bladder.

The prostate of the *bear* is confounded with the dilatation of the united vasa deferentia. It surrounds the beginning of the urethra, and forms a bed for the canal of variable thickness, according to the species.

In the *otter*, *weasel*, and *marten*, it consists of a thin layer, without any enlargement. In the *ichneumon*, there is a gland of considerable size, composed of distinct lobes, situated on the rectal aspect of the urethra; each lobe has a distinct duct.

In the *dog* and *cat*, it forms a large prominent collar around the urethra; it resembles the human prostate in structure, and mode of termination of its ducts.

In the *hyena*, it is of large size; and in the civet it forms two tubercles in front of the insertion of the vasa deferentia.

In the *marmott*, among the rodentia, it is divided into two lobes, and forms a considerable swelling around the commencement of the urethra.

The glandular covering of the vesiculæ seminales, which extends below the muscular structure of the urethra, represents the prostate gland in the *rabbit*.

In the *squirrel*, it is as long as the muscular portion of the urethra, of large size, ovoid in shape, flattened from above, and is divided into two lobes; it adheres to the urethra by two points, where its excretory ducts penetrate the canal.

According to Müller, in the *rat* genus, besides three glands of different structure on each side, the urethra is surrounded by a glandular mass, consisting of bunches of vesicles, representing the prostate.

* Vogel's Pathological Anatomy of the Human Body, translated by Dr. G. E. Day.

† Owen's Lectures on the Invertebrate Animals.

In the *agonti*, the prostates are composed of a trunk, divided into branches and ramusculi, terminating in vesicular extremities.

In the *guinea-pig*, the situation of the prostate is occupied by a number of tubes folded upon themselves, and connected together by loose cellular membrane.

The *elephant* has four prostate glands, two on each side, external to the vesiculæ seminales, and near their base; they are of unequal size, and very small in proportion to the size of the other glands connected with the generative function. They are muscular externally, and are indistinctly lobulated. They form a good illustration of the cellular type of prostates, each consisting of a principal cavity, into which smaller cavities open. The smaller cells represent so many *cul-de-sacs* of various sizes, communicating with each other and with the principal cavity; the excretory duct is of large size, and passes by the side of that of the neighbouring gland, to open separately in the urethra by the side of the veru montanum.

In the *wild boar* the prostate is divided into lobes, is very compact in its structure, and forms a considerable projection at the beginning of the urethra. There is also found in this animal a glandular mass, analogous to the prostate, surrounding the muscular portion of the urethra, thickest at the commencement of this canal, and surrounded by muscular fibres coming from the neck of the bladder.

In *solipedes* there are two prostates, situated by the side of the vesiculæ; the cavities of these are large, and the parenchyma small in quantity; they are covered by muscular fibres coming from the vesiculæ and neck of the bladder; their excretory ducts terminate by many orifices on either side of the ducts of the vesiculæ.

The *ruminants* have also two prostates, precisely similar to the preceding. They are larger in the ram and bull, and are composed of distinct lobes, each containing small cells, which communicate with a large central cavity; this opens by a duct in a large lacuna of the veru montanum, either internal to or behind the vas deferens. In the *stag*, *axis*, and *buffalo* they are smooth, and of a regularly oval shape, and have a central cavity communicating by large openings with smaller cavities; each has a single duct, which terminates generally behind the corresponding vas deferens. The only difference in this class is in regard to size; for in the *chamois* each is as large as a pullet's egg, and contains a proportionably large cavity; so that it has been occasionally mistaken for a reservoir of seminal fluid. In the seal, amongst the *quadrirèmes*, it resembles that of the otter. In the *cetacea* there is a large glandular mass, covering a large portion of the first part of the urethra, especially at the upper part, covered by a strong muscle. When a section is made, it is found to consist of large cells; its ducts open separately by numerous orifices on the urethra.

In the *marsupial* sub-class, as in the kangaroo, the prostate is found surrounding the commencement of the urethra, of large size, and conical in shape, with base behind, apex in front; it is surrounded by a strong musculo-membranous capsule. It exceeds in diameter the contracted bladder, and is made up of tubes ramifying perpendicularly to the urethra, which subdividing terminate in minute cœca upon the surface of the gland. It presents a similar arrangement in the *opossum*; whilst in the *wombat* its existence is doubtful.

Carus has described in birds a dilatation of the vas deferens, a rudimentary vesicula seminalis, and a small gland like a prostate near the termination of the vas deferens. This is not admitted by Owen. In the *ornithorynchus paradoxus* we find two round glandular bodies representing Cowper's glands, but which may be fairly regarded as a rudimentary prostate.

Amongst *amphibious reptiles*, glands analogous to the prostate, or Cowper's glands, are found. In the salamander they are composed of two lobes; one placed horizontally, and the other vertically; the former, in the common salamander is heart-shaped, with the point behind; and in its centre a fissure is seen. The vertical lobe is raised obliquely towards the dorsal aspect, so that an interval is left between them for the passage of the kidneys; a muscle separates the two.

In the *black salamander*, each gland is composed of two lobes. In the Tritons the part of the prostate which corresponds with the inferior lobe is still more complicated; it forms the wall of the vestibulum in the shape of a cup. Besides this, there are two pelvic prostates corresponding to the vertical lobe of the vestibular prostate of the salamander; they occupy the dorsal aspect of the vestibule and the pelvis, and each is subdivided into two lobes. Their excretory ducts open in the mesian line of the furthest point of the vestibule. The Tritons have a third prostate occupying a large portion of the abdominal muscles under the peritonæum. In structure they resemble those of the hedgehog.— (Cuvier.)

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(John Adams.)

PROTEIN, (from πρωτεύω, I am first,) is the name given by its discoverer, Mulder, to a chemical substance of the highest interest and importance; since it appears to form the basis of by far the greater portion of the bodies of all animals.

When pure *fibrin*, of which animal flesh or muscle chiefly consists, is analysed, it is found to be composed of $C_{40}\ H_{31}\ N_5\ O_{12}$ and a small quantity of sulphur and phosphorus. *Albumen*, whether obtained from the serum of the blood, white of egg, or any of the albuminous tissues of the body, is found also to consist of $C_{40}\ H_{31}\ N_5\ O_{12}$ and a little sulphur and phosphorus. *Casein*, too, or the curd of milk, yields on analysis $C_{40}\ H_{31}\ N_5\ O_{12}$ and a little sulphur, differing from the others in not containing any phosphorus. Hence it appears that *fibrin*, *albumen*, and *casein*, are, chemically speaking, almost identically the same; and that if we were enabled to separate from each the minute portion of sulphur and phosphorus, we should obtain a compound in every case the same. Such a substance is *protein*; so called from its being the initial letter, as it were, of all this class of organic principles.

I shall first describe it as obtained artificially, together with the changes produced upon it by reagents, and afterwards speak of its more common natural modifications, which play so important a part in building up the fabric of organic beings.

Protein is most readily obtained from the white of egg, which, as is well known, consists of a solution of nearly pure albumen, contained in a delicate network of cellular membrane. This substance should be well beaten up, in order to break the minute cells in which the albumen is lodged, mixed with about an equal bulk of water, and filtered through a linen cloth to separate the cellular matter, which is insoluble in water; or it may be allowed to stand until this has subsided to the bottom of the vessel, when the clear liquid may be poured off, or removed by means of a syphon. The solution should then be evaporated to dryness on a water bath, the residue pounded in a mortar, and washed successively with alcohol, ether, and dilute hydrochloric acid, by which means it is purified from extractive matters, fat, phosphate of lime, and the other salts with which it is associated. The pure albumen thus obtained is digested for several hours in a dilute solution of caustic potash, at a temperature of from 120° to 130°; it readily dissolves in the alkaline solution, and the sulphur and phosphorus are gradually separated, forming sulphuret of potassium, and phosphate of potash. Acetic acid is now added in very slight excess, when the protein separates in the form of a white flocculent precipitate, which, when washed with water until all soluble matter is removed, and dried at 212°, is pure protein. In order to asertain, however, whether the whole of the sulphur is removed, a small quantity should be dissolved in potash, and some of the solution boiled in two test tubes, to one of which a drop of solution of acetate of lead is added. They will both become rather brown, owing to the decomposition of the protein; but if any sulphur is present, the portion to which the lead had been added will become, after boiling for a few minutes, much darker in colour than the other, owing to the formation of sulphuret of lead.

Protein, when dry, is a hard, semitransparent brownish yellow substance, having a good deal the appearance of amber. It is without taste or smell, and when exposed to damp air rapidly absorbs moisture, which may be expelled by heating it to about 220°. When further heated it melts, and almost immediately afterwards begins to decompose, leaving a residue of charcoal, which, if ignited for some little time in the air, burns completely away, leaving scarcely a trace of incombustible ash. Protein is insoluble in water, alcohol, and ether; it appears to combine with most of the mineral acids, forming compounds which may be considered neutral, some of which are soluble in water, though insoluble in an excess of the acid. Tribasic phosphoric, and acetic acids, however, do not reprecipitate it when added in excess. It combines also with the alkalies, giving rise to soluble compounds, from which the protein may be again separated by the addition of an acid. It may be thrown down in an

nsoluble form from any of its acid solutions by the ferrocyanide and ferridcyanide of potassium, which are among the most delicate tests for it; also, by absolute alcohol, tannin, many of the metallic salts, and by carefully neutralizing with an alkali.

Tritoxide of protein. — Though protein may be said to be absolutely insoluble in water, it may by prolonged ebullition with access of air be rendered completely soluble. This is owing to the formation of a soluble oxide of protein, represented by the formula $C_{40}\ H_{31}\ N_5\ O_{15} + HO$, containing three additional equivalents of oxygen, and which Mulder has called *tritoxide of protein.* This interesting compound may be more easily prepared from the *chlorite of protein* (which I shall presently describe) by the addition of ammonia; the muriate of ammonia which is formed at the same time being afterwards separated by washing with alcohol.

Tritoxide of protein has, when dry, very much the same appearance as protein; it is readily soluble in water, nearly insoluble in alcohol, and completely so in ether. It dissolves in sulphuric and hydrochloric acids and the alkalies, but is precipitated from its solution in water by dilute sulphuric acid, tannin, and several metallic salts, forming compounds with their oxides, having for the most part the formula $(C_{40}\ H_{31}\ N_5\ O_{15} + MO) + (C_{40}\ H_{31}\ N_5\ O_{15} + HO)$. With nitric acid it behaves like protein, becoming yellow, and forming xanthoproteic acid. Water in which meat has been boiled, as broth, soup, &c., owes its nourishing properties mainly to the tritoxide of protein which is formed during ebullition; and according to Mulder, both this and the binoxide are formed in meat during the process of roasting.

Binoxide of protein. — The other compound of protein and oxygen just alluded to, called by Mulder the *binoxide*, consists of $C_{40}\ H_{31}\ N_5\ O_{14}$ or the elements of protein plus two equivalents of oxygen. Both this and the tritoxide exist ready formed in the buffy coat of the blood, which, according to Mulder, consists chiefly of these two oxides. Binoxide of protein may be obtained by boiling fibrin in water for many hours, when the protein gradually combines with at first two, and eventually three equivalents of oxygen, becoming successively binoxide, and (if the ebullition is continued long enough) tritoxide; the latter dissolves as it is formed, and may be separated from the insoluble binoxide by washing with water. This process is, however, tedious, and it is more readily obtained from hair, in the following manner. The hair should be freed from grease by washing with ether, and dissolved in rather a dilute solution of caustic potash, with the aid of a gentle heat, not exceeding 120° or 130°. A mixed solution of protein and its binoxide is in this way obtained, from which the protein is first separated by neutralizing the solution with acetic acid, and after filtration the binoxide is precipitated by the further addition of a decided excess of acid. It appears as a yellowish flocculent precipitate, and when washed and dried has a dark resin-like appearance.

Bouchardat obtained a substance by digesting moist fibrin in water acidified with one or two-thousandth of its weight of hydrochloric acid, in which it gradually dissolved, which he called *albuminose;* it has since been prepared and analysed by Mulder, who considers it to be identical with binoxide of protein; but Liebig, who has recently examined it, says that it cannot be obtained free from sulphur, and consequently that it is not pure binoxide of protein. This oxide is insoluble in water, alcohol, and ether, but dissolves in most of the dilute acids, and in solutions of potash and ammonia; it is precipitated from its acid solutions by ferrocyanide and ferridcyanide of potassium, and several other metallic salts. Nitric acid decomposes it, forming xanthoproteic acid, but the yellow colour produced by it is less intense than that obtained with protein.

These oxides of protein possess considerable physiological interest, from the circumstance that they are contained in the blood, in small quantity during health, but much more abundantly in some forms of disease. It is probable that they are formed during every act of respiration by the action of the inspired oxygen on the globules or fibrinous matter of the blood; and Mulder is of opinion that it is through their instrumentality that the atmospheric oxygen is conveyed to the capillaries, there to be employed in effecting the necessary changes in the substance of the body. During fever, when respiration goes on with more than ordinary rapidity, these oxides are formed in much larger quantity; hence the buffy coat of diseased blood, which was formerly considered to be merely fibrin, consists almost entirely of oxidized protein; and pus, false membranes, and other morbid products contain it in considerable quantity.

Mulder has recently obtained a third oxide of protein, represented by the formula $C_{40}\ H_{31}\ N_5\ O_{20}$ or protein plus eight equivalents of oxygen. As it has not, however, been found to exist naturally in the animal body, it is inferior in point of interest to the other two. Like the tritoxide it is soluble, and is obtained by boiling glutin or yeast for a length of time in water.

By the action of chemical reagents on protein a multitude of new compounds are formed, most of which have been only imperfectly examined, and indeed possess but little real interest. I will describe a few of the most important.

Protein and chlorine. — When a current of chlorine is passed through a solution of albumen, or any of the other modifications of protein, a substance is produced, containing $C_{40}\ H_{31}\ N_5\ O_{15}\ Cl_1$, which Mulder considers to be a *chlorite of protein*, $(C_{40}\ H_{31}\ N_5\ O_{12} + Cl\ O_3)$. It appears to be formed at the expense of three equivalents of water; three equivalents of hydrochloric acid and one of chlorous acid being simultaneously produced, the latter uniting with the protein. It separates as a snow-white flaky precipitate, and

when dried, is hard, semitransparent, and nearly colourless. This substance is sometimes called *chloroproteic acid*, since it is found to combine without decomposition with several metallic oxides. When treated with ammonia, however, it is decomposed, nitrogen gas is given off, and tritoxide of protein is formed, together with hydrochloric acid, which combines with the excess of ammonia. This is the most convenient way of preparing the tritoxide, as it is easily separated from the muriate of ammonia by washing with alcohol, in which it is insoluble.

Protein and nitric acid. — By the action of nitric acid on protein compounds, oxalic acid, ammonia, nitrogen, nitric oxide, together with a new compound called *Xanthoproteic acid*, are obtained; which latter, being insoluble, is readily purified by washing with water. Xanthoproteic acid is of a bright yellow colour, from which circumstance it derives its name: it reddens litmus, is uncrystallizable, tasteless, and, when strongly heated, does not melt, but is decomposed, giving off the smell of burnt feathers. It is soluble in strong acids, and when water is added to the solution, a precipitate, containing both the acids in a loose state of combination, is thrown down. It forms with metallic oxides true salts, most of which are of a deep orange-colour, and insoluble in water; the alkaline xanthoproteates, however, are soluble. It is bibasic, and consists of $C_{34}\ H_{24}\ N_4\ O_{12} + 2\ HO$. The troublesome and indelible stain which nitric acid causes when dropped on the skin is owing to the formation of this substance.

Protein and sulphuric acid. — When protein is treated with strong sulphuric acid it forms a white insoluble compound, called by Mulder *sulphoproteic acid*, containing C_{40}, H_{31}, N_5, O_{12}, + SO_3. To purify it, it should be washed with cold water as long as the washings give a precipitate with baryta water: when dry, it is hard, tough, semitransparent, and nearly colourless; it forms with alkalies, soluble, and with the other oxides, insoluble, sulphoproteates.

There is another compound of protein and sulphuric acid, called by Mulder *sulphobiproteic acid*, which is formed when dilute sulphuric acid is gradually added to a solution of protein in acetic acid: it appears to consist of two equivalents of protein, two of water, and one of sulphuric acid, and is represented by the formula $C_{80}\ H_{62}\ N_{10}\ O_{24} + 2\ HO + SO_3$. If a protein compound be heated with sulphuric acid it becomes purple, but the colour disappears on dilution with water.

Protein and hydrochloric acid. — Concentrated hydrochloric acid slowly dissolves protein even at common temperatures, and still more readily when gently warmed: the solution is at first yellowish, but if the air is not excluded, the colour soon changes to a deep blue or purple. The appearance of this blue colour is one of the most striking tests for protein and its modifications, fibrin, albumen, and casein, as it is produced in them all by hydrochloric acid. When allowed to boil, if the acid is strong, a black substance similar to ulmic acid is formed, together with muriate of ammonia.

Protein and potash. — The action of potash on protein possesses considerable interest. When treated with a dilute solution of the alkali, in the cold, it readily dissolves, and, according to Mulder, a little ammonia is always given off, however dilute the alkaline solution may be. When boiled in a strong solution of potash it is completely decomposed; ammonia, carbonic, and formic acids are formed, together with three new compounds, which have been called *leucin*, *protid*, *erythroprotid*. To obtain these substances in a state of purity, the following process may be adopted. The protein compound is boiled with solution of potash as long as any ammonia is given off, and then neutralized with sulphuric acid, which disengages the carbonic acid and combines with the excess of potash: the solution is then evaporated to dryness on a water-bath, by which means the greater part of the formic acid is volatilized. The organic compounds are then separated from the sulphate of potash by repeated boiling in alcohol, in which they are all more or less soluble. On cooling, the alcoholic solution deposits the erythroprotid, which is of a reddish-brown colour, and nearly insoluble in cold alcohol. When left for a short time to spontaneous evaporation, the leucin crystallizes out, and the liquid then contains only protid, with a trace of erythroprotid, and a little formiate of potash.

Erythroprotid, when pure, is of a fine red colour; it is soluble in boiling alcohol and in water, and is precipitated from its solutions, of a rose red colour, by many of the metallic salts, as those of silver, mercury, and lead: it is thrown down also by tannic acid. When a current of sulphuretted hydrogen is passed through its aqueous solution, it gradually becomes colourless; but if the solution, thus treated, be kept in vacuo a short time, the colour returns. The formula of erythroprotid is $C_{13}\ H_8\ NO_5$.

Protid ($C_{13}\ H_9\ NO_4$) may be separated from the impure alcoholic solution by diluting with water, and precipitating with subacetate of lead, which throws down protid, but not erythroprotid, which latter is also present in small quantity. The precipitate is washed with water, and decomposed by sulphuretted hydrogen; the solution is filtered and evaporated, after which the protid is left in a state of purity. It is of a pale yellow colour, amorphous, and, when dry, very brittle. It differs from erythroprotid in not being precipitated from its solutions by any of the metallic salts except basic acetate of lead; while erythroprotid is not affected by that reagent: consequently if the two exist together in solution, the erythroprotid may be thrown down by the neutral acetate, and the protid by the basic salt.

Leucin, which gradually separates when the alcoholic solution is concentrated, is a crystalline substance closely resembling chloresterine in appearance: it consists of $C_{12}\ H_{12}\ NO_4$.

It is tolerably soluble in water and alcohol, but quite insoluble in ether; and when heated to about 340° it sublimes without decomposition. When treated with nitric acid, a crystalline *nitroleucic acid* is formed, consisting of $C_{12} H_{12} NO_4 + NO_5 + HO$.

Mulder has attempted to explain by the following equation how the elements of protein may dispose themselves, in order to produce the compounds just described.

$$\left.\begin{array}{lllllll}
2 & \text{Equivts.} & \text{Erythroprotid} & C_{26} & H_{16} & N_2 & O_{10} \\
2 & ,, & \text{Protid} \ldots\ldots & C_{26} & H_{18} & N_2 & O_8 \\
2 & ,, & \text{Leucin} \ldots\ldots & C_{24} & H_{24} & N_2 & O_8 \\
4 & ,, & \text{Ammonia} \ldots & & H_{12} & N_4 & \\
2 & ,, & \text{Carbonic acid} & C_2 & & & O_4 \\
1 & ,, & \text{Formic acid} & C_2 & H & & O_3 \\
\hline
 & & & C_{80} & H_{71} & N_{10} & O_{33}
\end{array}\right\} = \left\{\begin{array}{llllll}
2 \text{ Equivts.} & \text{Protein} \ldots & C_{80} & H_{62} & N_{10} & O_{24} \\
9 \quad ,, & \text{Water} \ldots & & H_9 & & O_9 \\
\hline
 & & C_{80} & H_{71} & N_{10} & O_{33}
\end{array}\right.$$

Equations of this kind, though sometimes of great service in simplifying complicated chemical changes, are always to be looked upon merely as representing *possibilities*, and should not be adopted without great caution; much mischief has indeed already been done from the too ready credence in the truth of hypotheses which have thus been made to appear simple and striking, though really in the highest degree at variance with what further research has proved to be the truth.

The action of potash on protein and its compounds derives additional interest from the circumstance that it may afford a clue to the manner in which the gelatinous tissues of the body are formed from protein compounds, a problem at present very far from being satisfactorily solved. Both protid and erythroprotid are somewhat similar in composition to chondrin and glutin; and leucin, which Mulder considers to be actually a constituent of protein, may be obtained also from gelatine, clearly showing some connection to exist between the protein and gelatine compounds: moreover we find the gelatinous tissues formed in the herbivora, though not a trace of any analogous substance can be detected in their food. These circumstances tend to the conclusion that the chondrin and glutin of the herbivora at least, are in some way derived from the proteinaceous matters of the food, and Mulder has suggested that it may be owing to a change produced by the free alkali of the serum, not unlike that which I have described as the effect of the action of potash on the protein compounds. Glutin consists, according to that chemist, of $C_{13} H_{10} N_2 O_5$, and it is easy to represent by a chemical equation how such a compound may be formed from either protid or erythroprotid. When these latter substances are formed in the laboratory by the decomposition of protein by potash, it is probable that two equivalents of ammonia are at the same time produced; and we may conceive that in the living body the elements which, when not so circumstanced, unite to form ammonia, remain combined with those of protid and erythroprotid; in that case we should have compounds containing protid *plus* ammonia, $C_{13} H_9 NO_4 + NH_3 = C_{13} H_{12} N_2 O_4$: and erythroprotid *plus* ammonia, $C_{13} H_8 NO_5 + NH_3 = C_{13} H_{11} N_2 O_5$. If now we suppose that these two hypothetical substances, $C_{13} H_{12} N_2 O_4$ and $C_{13} H_{11} N_2 O_5$ become united, the one to three equivalents, and the other with one equivalent of oxygen, a supply of which is always present in the arteries, we should have in the case of protid, $C_{13} H_{12} N_2 O_7$ or $C_{13} H_{10} N_2 O_5 + 2 HO$; and in that of erythroprotid $C_{13} H_{11} N_2 O_6$ or $C_{13} H_{10} N_2 O_5 + HO$, so that in both cases glutin *might* be formed. This hypothesis is highly ingenious and interesting, though the probability of its correctness is somewhat lessened by the circumstance that neither leucin, protid, nor erythroprotid, have yet been detected in the animal organism; and moreover it is uncertain whether the alkaline reaction of the blood is owing to the presence of *free* alkali, or of tribasic phosphate of soda.

We now come to the consideration of the natural modifications of protein, which we find composing the chief bulk of the bodies of animals, viz. *fibrin*, *albumen*, and *casein*.

Fibrin. — This is a substance of the highest importance in the animal economy, since it is the material of which the solid framework of the muscles and some other tissues mainly consist; and it is also found dissolved in the blood, from which it separates spontaneously after removal from the body, forming the clot or crassamentum. The following table shows the average proportion of fibrin in several animal products.

100 *parts*	*Fibrine.*	
Blood of the hog contain	0·46	
„ ox	0·37	
„ sheep	0·30	
Beef (muscle of)	20·0	Including a little albumen.
Veal „	19·0	
Mutton „	22·0	
Pork „	19·0	
Chicken „	20·0	
Cod „	14·0	
Haddock „	13·0	
Sole „	15·0	
Calf's sweetbread (thymus)	8·0	

Fibrin may be obtained from lean animal flesh by cutting it into thin slices and washing with water till it is colourless; it is, however, impossible to obtain it pure in this way, as it is always associated with fatty matters, nerves,

and membrane. It may be obtained in a state of purity from the blood, in which, as already mentioned, it exists in a soluble condition, but remarkably prone to assume the solid form as soon as removed from the body. The blood, as soon as drawn, should be rapidly beaten up with a bundle of wires or twigs, to which the fibrin attaches itself in the form of solid amorphous filaments, coloured red by a quantity of the globules entangled in its pores during the coagulation; these latter may be removed by placing the coagulum in a piece of linen cloth, and washing with a stream of cold water until all colour disappears. It still contains fatty matters, inorganic salts, and a considerable quantity of water, all which may be removed by drying on a chloride of calcium bath at a temperature of about 250°, pounding the hard mass in a mortar, washing with alcohol, ether, and dilute hydrochloric acid, and lastly, macerating in water until all soluble matter is dissolved out, when it should be again thoroughly dried. Thus prepared, it is of a yellowish colour, hard, brittle, and, when perfectly free from fat, transparent. It is tasteless, and insoluble in alcohol, ether, and water; but in the latter it softens, swells up, and reassumes the appearance it had previous to desiccation. Though insoluble in both hot and cold water, it is converted by prolonged boiling, first into binoxide and eventually into tritoxide of protein, which latter is soluble in water. Most of the acids, when in a concentrated state, cause fibrin to swell up and assume a gelatinous appearance. It was observed by Scherer that when moist fibrin is placed in an atmosphere of oxygen, it has the property of absorbing and retaining a portion of the gas; an effect no doubt accompanied by the formation of one or more of the oxides of protein: it is probable that a portion of the fibrin of the blood undergoes a similar change, since these oxides are always present in arterial blood both in health and disease, especially in some forms of fever, when, by an accelerated respiration, a larger amount of oxygen is introduced into the system.

Fibrin and sulphuric acid.—With strong sulphuric acid dry fibrin becomes yellowish and gelatinous, considerable heat being at the same time evolved, sufficient indeed, provided the quantity be large, to cause complete decomposition, when it blackens, and sulphurous acid is given off. When water is added, the gelatinous mass contracts suddenly in bulk, and the white curdy matter thus obtained consists chiefly of sulphoproteic acid, already described.

Fibrin and nitric acid.—Fibrin behaves with nitric acid in a similar manner to protein, giving rise to the formation of xanthoproteic acid.

Fibrin and acetic acid.—When treated with concentrated acetic acid, it almost immediately becomes gelatinous, and if water be added and the mixture warmed, it readily dissolves, especially if the fibrin be obtained from a young animal: this solution when evaporated leaves the fibrin with precisely the same properties which it had previous to dissolution. If another acid, as the sulphuric, be added to the acetic solution, it combines with the protein, forming generally an insoluble compound, as in the case of the sulphobiproteic acid. If the acetic acid solution be neutralized with potash, the fibrin is precipitated, but is redissolved if the alkali be added in excess.

Fibrin and hydrochloric acid.—When treated with strong hydrochloric acid fibrin becomes gelatinous, and gradually dissolves, giving the solution a beautiful blue colour, which is characteristic of all the protein compounds: if this solution be diluted with water, a white precipitate appears, which is a compound of hydrochloric acid and protein. When the acid is very dilute it has the property of gradually dissolving fibrin; and as a trace of free hydrochloric acid is generally to be found in the stomach, it is probable that its solvent action tends to assist materially in the process of digestion. Bouchardat says that water containing only one two-thousandth of its weight of hydrochloric acid causes moist fibrin to become gelatinous, and eventually to dissolve, leaving only a small quantity of insoluble matter, which he calls *epidermose:* the soluble portion he has called *albuminose*, but Mulder considers it binoxide of protein, which assertion, however, has recently been contradicted by Liebig.

Fibrin and potash.—Fibrin dissolves readily in a solution of potash, even when very dilute. If the solution be gently heated, the fibrin is gradually decomposed, the sulphur and phosphorus being removed, and protein remains combined with the potash, from which it may be separated by neutralizing with acetic acid. Ammonia behaves in a similar manner, but its action is much less rapid.

Fibrin readily dissolves in the gastric juice, which appears to owe its solvent action both to the organic principle *pepsine*, and also to a little free hydrochloric acid in the stomach, which is derived from common salt. The same effect may be produced artificially by an infusion of the fourth stomach of the calf, to which a little hydrochloric acid has been added.

It is curious that the presence of certain salts, as nitrate of potash and sulphate of soda, prevents the coagulation of the fibrin of the blood; and even when coagulated, provided it be still moist, it is again dissolved by some saline solutions, as, for instance, muriate of ammonia. Moreover, M. Denis has found that if moist fibrin be digested in a solution of nitrate of potash containing a little soda, at a temperature of about 100°, it becomes gradually converted into a substance in almost every respect identical with albumen, being soluble in water, and coagulable by heat. This change is most readily produced when the fibrin employed has been obtained from venous blood, by allowing it to coagulate spontaneously; while if it be separated by agitation, or if the blood be arterial, it scarcely experiences any alteration in the saline solution. Changes of this kind, of the several modifications of protein into one another, are constantly occurring in the animal economy, and the great similarity

of their composition must render such metamorphoses comparatively easy.

The composition of fibrin is $C_{400}\ H_{310}\ N_{50}\ O_{120}$ SP, or ten equivalents of protein united to one of sulphur and phosphorus. It also usually contains from 1·3 to 2·3 per cent. of inorganic matter, chiefly phosphate and sulphate of lime, and alkaline salts.

Albumen. — This important compound, so called from its constituting the solid matter of white of egg, exists in two conditions, perfectly distinct in physical properties from each other; the one soluble and miscible with water in all proportions, as it is found in the serum and white of egg; the other solid, and quite insoluble in water, as in white of egg after boiling. The solid form is also met with, in a somewhat modified condition, in the albuminous tissues of the body, as the brain, spinal cord, nerves, &c. The proportion of albumen contained in some of the animal products may be seen in the following table.

100 *parts.*	*Albumen.*
Blood of ox	18·6
„ hog	18·58
„ goat	19·28
„ sheep	18·35
East India isinglass	7·2 to 13·5
Egg, white of	15·5
„ yolk of	17·47
Liver of ox, parenchyma of	20·19
Sweetbread (thymus) of calf	14·0
Muscle of beef	2·2
„ veal	3·2
„ pork	2·6
„ roedeer	2·3
„ pigeon	4·5
„ chicken	3·0
„ carp	5·2
„ trout	4·4
Brain	7·0
Optic nerve	22·0

Albumen, in a state of absolute purity, has been but imperfectly examined. It may be prepared by the following process, recently adopted by Wurtz. A quantity of white of egg is well beaten up with about twice its bulk of water, and strained through linen to separate the cellular membrane. A solution of subacetate of lead is cautiously added, which throws down a copious precipitate; but care must be taken to avoid adding an excess of the precipitant, which would partly redissolve it. The precipitate should be well washed, and while suspended in water a stream of carbonic acid passed through it: the liquid soon becomes frothy, owing to the decomposition of the albuminate of lead and liberation of free albumen, carbonate of lead being precipitated. The solution of albumen, after filtration, generally contains a trace of oxide of lead, which may be separated by adding a few drops of solution of sulphuretted hydrogen, and warming the liquid till it just begins to coagulate, when the whole of the sulphuret of lead is entangled in the coagulum: the liquid, which after another filtration is clear and transparent, should be cautiously evaporated at a temperature not exceeding 120°, when it leaves a residue of pure albumen.

Albumen thus prepared is brittle, semitransparent, without taste or smell, and almost colourless. When burnt it leaves a very minute quantity of inorganic residue, which seems to be quite free from alkali: this fact is important, as it tends to settle a question which has been long disputed, viz. whether pure albumen is really soluble in water, or whether its solubility is due to the free alkali with which it is usually associated. If dry albumen be digested with water in a moderately warm place it readily dissolves, but a small insoluble residue always remains. According to Wurtz a solution of pure albumen begins to coagulate when heated to about 140°; but if it be perfectly dry it may be raised to 280° or 290° without losing its solubility. It appears to have a slightly acid reaction, and if digested at a gentle heat, with a solution of carbonate of soda, it displaces the carbonic acid and combines with the soda. The albumen contained in white of eggs is composed of $C_{400}\ H_{310}\ N_{50}\ O_{120}$ SP, or ten equivalents of protein *plus* one equivalent of sulphur and phosphorus; while that obtained from the serum contains an additional equivalent of sulphur, or $C_{400}\ H_{310}\ N_{50}\ O_{120}\ S_2$ P. It is usually associated with from two to five per cent. of inorganic salts.

The appearances presented by albumen with reagents are in most cases very similar to those of protein, which I have already described, and its solution in hydrochloric acid has the characteristic blue colour. Most of the acids precipitate it from its solution, but this is not the case with tartaric, acetic, and tribasic phosphoric acids. Hence nitric acid is often used to detect albumen in the secretions. Another delicate test for albumen is ferrocyanide of potassium, which gives a white precipitate even with acid solutions; the ferridcyanide of potassium gives a yellowish precipitate. The application of heat is also a good test for this principle: but as the presence of free alkali tends to prevent its coagulation, it is always advisable to add at the same time a drop or two of nitric acid, when, if both cause a precipitate, the presence of albumen may be considered certain: it must be remembered too that the presence of those acids which do not precipitate albumen, such as the tribasic phosphoric, tartaric, and acetic, also interferes with its coagulation by heat. Many of the metallic salts, when added to albumen, form insoluble precipitates, which are in most cases compounds of albumen with the acid or the base of the salt. A drop of a solution of bichloride of mercury will thus indicate the presence of albumen, even when diluted with two thousand times its weight of water; and this property of forming an insoluble compound has been taken advantage of in the treatment of cases of poisoning with the bichloride, when the white of egg has been found of great service; the white of one egg being sufficient, according to the experiments of Peschier, to neutralize the effects of four grains of the poison. Albumen is precipitated from its solutions by many

other substances, as tannic acid, creosote, alcohol, and ether; and its coagulation may also be effected by a current of voltaic electricity. When taken into the stomach it is coagulated by the free acid usually present.

The curious change which albumen undergoes from the soluble to the insoluble condition is but very imperfectly understood, and it is not known how far the physical state of that coagulated by heat resembles that rendered insoluble by alcohol and the other precipitants. It is said that if an egg be smeared with oil immediately after it is laid, and afterwards exposed to heat, the coagulation is incomplete. Coagulated white of egg readily dissolves in alkaline solutions, and is reprecipitated unchanged if the solution be supersaturated with sulphuric acid. If it be digested at a temperature of about 120°, with a tolerably strong alkaline solution, the sulphur and phosphorus are separated from the protein; but if the alkaline solution be boiled, further decomposition takes place; ammonia is given off, and leucin, protid, and other compounds are formed. If the alkaline solution in which white of egg is boiled be rather weak, it acquires, after some hours' boiling, a smell precisely similar to that of boiled fowl. Though perfectly insoluble after coagulation, both in cold and boiling water, it appears to dissolve when heated under pressure to about 300° with that liquid, and the solution thus formed behaves in every respect similar to uncoagulated albumen. When exposed to the air in a moist state albumen is extremely prone to enter into putrefaction; but if dry it may be preserved unchanged for any length of time. If boiled for several hours in water it is converted into tritoxide of protein, without passing through the intermediate stage of binoxide, in which respect it differs from fibrine.

The ready convertibility of albumen into the other protein compounds, as well as into many other animal tissues, is well illustrated in the phenomena of incubation; where we find all the various compounds which are contained in the hatched bird, derived more or less directly from this substance, which, together with a yellow oil and some inorganic salts, constitutes the whole of the solid contents of the egg.

Casein is the form in which protein appears in the milk, where it constitutes the chief source of nourishment to the young animal, for which purpose it is admirably adapted, not only from the protein it contains, which is readily converted into fibrin and albumen, but also on account of the inorganic salts, especially phosphate of lime, with which it is always associated. The proportion of casein contained in the milk of different animals varies considerably; and a still more striking variation is caused by the food of the animal, as may be seen in the following table.

100 *parts.*	*Casein.*
Cow's milk	4·48
,, fed on hay	3·0
,, ,, turnips	3 0
,, ,, clover	4·0
Cow's milk potatoes and hay, 3·3 to	5·1
Ewe's milk	4·5
Goat's milk	4·02
Ass's milk	1·82
Woman's milk	1·52

Casein is scarcely known in a state of absolute purity, as it is extremely difficult to separate it entirely from inorganic impurities: these consist chiefly of lime, potash, soda, and iron, combined with phosphoric, sulphuric, and hydrochloric acids. The purest specimens prepared by Rochleder left, when burnt, only 0·3 per cent. of incombustible ash; but as it is generally prepared it contains considerably more, sometimes as much as 10 per cent. It appears to be insoluble in water, and owes its solubility in milk to the small quantity of potash which is always present. The best process for obtaining casein is the following. A quantity of milk is first evaporated to dryness on a water-bath, and the dry residue, reduced to powder, is boiled in successive portions of ether until the whole of the fatty matter is removed; the impure curd should then be evaporated to dryness, and the soluble part separated by digesting in water. To this solution, after filtration, alcohol is added to throw down the casein, which, however, is often still contaminated with a little sugar of milk: this may be removed by again dissolving in water, and once more precipitating the casein by alcohol. When dry it resembles albumen very much in appearance, and its behaviour with reagents is in most cases very similar; it differs from it chiefly in not coagulating when heated, and it is precipitated by all the acids, but redissolves in an excess of most of them. Sulphuric acid throws down a compound which has been called sulphate of casein; this precipitate always contains a certain quantity of phosphate of lime, and it is only by repeatedly dissolving it in an alkaline solution, reprecipitating with dilute sulphuric acid, and well washing with boiling water, that it can be obtained in a state of purity. When milk or a solution of casein is heated under ordinary circumstances, a thin skin is formed on the surface, which, if removed, is quickly replaced by another; this substance has never been properly examined; but as it is not formed unless oxygen is present, it is probably the result of oxidation. Casein is precipitated from its solutions by ferrocyanide and ferridcyanide of potassium, provided the solution is not alkaline, and still more perfectly if a little acetic acid is present. Lactic acid also readily coagulates casein; but the coagulation appears to be most completely effected by the lining membrane of the stomach of the young animal, an action due either to lactic acid, or, what is perhaps more probable, to the presence of pepsine.

Casein has been found in some of the animal fluids besides milk: the saliva, the bile, pancreatic juice, and perhaps the blood, all contain it in more or less notable quantity. It affords another instance of the admirable adaptability of this interesting class of compounds

very similar to that already mentioned when speaking of albumen: in the milk, which is the sole food on which the young of most animals subsist, no other protein compound has been detected; but no sooner has it become the food of the young animal which it is intended to nourish, than it is for the most part converted into fibrin and albumen, thus furnishing blood and muscle, together with most of the other tissues of the body, which, though less directly, are scarcely less certainly products of the decomposition of this substance. The composition of casein is represented by the formula $C_{400}\ H_{310}\ N_{50}\ O_{120}\ S$, or ten equivalents of protein united to one equivalent of sulphur, thus differing from fibrin and albumen in not containing any phosphorus.

There is another modification of protein, very similar to casein in its properties and composition, which has been called both *globulin* and *crystalline*, from the circumstance that it is found surrounding the blood globules and also in the crystalline lens of the eye. It appears to contain no phosphorus and less sulphur than casein, and is composed, according to Mulder, of fifteen equivalents of protein united to one of sulphur.

The form in which protein exists in hair, horn, nails, and the epidermis, and called by Simon *keratine*, has been but imperfectly examined. That these substances are composed chiefly of protein is proved by the circumstance that if a solution of them be made in caustic potash and neutralized with acetic acid, a copious precipitate of protein is thrown down. It is probable that other modifications of protein will hereafter be found to exist in the animal body, but those which I have now described are all which have hitherto been detected.

The animal body, however, is not the only source from which protein and its compounds are to be obtained. The researches of modern chemists have led to the interesting fact that they exist in the vegetable kingdom also, and that they are there so extensively disseminated that not a leaf, a seed, or a twig, in any of the various tribes of plants, is free from them; and it is highly probable that the whole of the protein compounds constituting the bodies of animals are derived from plants. In the present state of analysis it is perhaps too much to say that the forms in which we find protein in vegetables are absolutely the same, with regard to the minute quantities of sulphur and phosphorus, as those found in animals; but as far as we are able to judge from similarity of properties, we may safely divide them in the same way as the analogous animal principles; viz. into *vegetable fibrin*, *vegetable albumen*, and *vegetable casein*. They all yield, when heated with strong hydrochloric acid, blue or purple solutions; and when they are digested with a solution of potash, and neutralized with acetic acid, protein is invariably produced.

Vegetable fibrin is found most abundantly in the seeds of the *cerealia*, as wheat, oats, &c.: it is also found dissolved in the juice of most plants, especially that of grapes, carrots, turnips, and beetroot, from which it shortly separates in the form of a flocculent precipitate when taken from the plant and allowed to stand. The readiest way of preparing it is to knead wheaten flour into a paste with water, and then wash it on a linen cloth with a stream of cold water until the whole of the starch is removed, which is known by the water passing through quite clear: the viscous mass which remains on the cloth is subsequently purified by washing with alcohol and ether, in both of which the fibrin is insoluble. When dry it is a hard horny-looking substance, semitransparent, without taste or smell, and sufficiently heavy to sink in water, in which it is insoluble. Phosphoric and acetic acids readily dissolve it; and it is reprecipitated in the form of white flocks from its acid solution by carbonate of ammonia and ferrocyanide of potassium, and yellowish by tincture of galls; it is also precipitated by bichloride of mercury and some other metallic salts. It is perfectly soluble in solution of potash even when very dilute, and if the quantity of fibrin dissolved be large, the liquid loses its alkaline flavour.

Vegetable albumen is found to exist very abundantly in the juices of most plants, and still more so in nuts, almonds, and other oily seeds, where it is usually associated with casein. It may be easily recognized by boiling the expressed juice of any of the common culinary vegetables after the fibrin has separated, when it coagulates in a manner similar to animal albumen. It may be obtained in a tolerably pure state by boiling the filtered juice of any of the *leguminosæ*, and washing the precipitate with alcohol and ether. It closely resembles animal albumen in properties, and is distinguished from vegetable fibrin by its solubility in water, and from vegetable casein by coagulating when heated.

Vegetable casein has also been called *legumine*, from the circumstance of its being found most abundantly in the *leguminosæ*, though it is by no means confined to that tribe of plants: it is also present in considerable quantity in company with albumen in most of the oily seeds, and in the juices of most nutritious vegetables. It may be obtained by the following process. Peas or beans should be soaked in moderately warm water for some hours until they are sufficiently soft to allow of their being mashed in a mortar: the pasty mass is then mixed with a large quantity of water, which dissolves the casein, and thrown upon a cloth to filter. The starch passes through the filter together with the solution of casein, and if allowed to stand, gradually subsides to the bottom: when the liquid is clear, it is decanted by means of a syphon, and slightly supersaturated with acetic acid, which determines the precipitation of the casein in an impure state, but readily purified by washing with alcohol and ether. Vegetable casein resembles that obtained from milk in most of its properties; gives the same insoluble skin when heated in contact with the air; and is precipitated from its aqueous solution of alcohol and several of the metallic oxides: it is also thrown down by both vegetable and mineral acids, redissolving

in an excess of the former, except the acetic, and insoluble in excess of the latter. If a solution of casein be allowed to stand some time, lactic acid is gradually formed, which causes it to coagulate, and putrefaction then begins, which, if any sugar is present, determines in it the alcoholic fermentation.

The various forms of protein which are found constituting the muscles, tissues, and solid matters of the blood of animals, are thus evidently derived from the vegetable kingdom; that silent but ever active laboratory in which so much of the chemical economy of nature is carried on. From the gaseous matters of the atmosphere, more especially carbonic acid, ammonia, and watery vapour, the organic elements, carbon, oxygen, hydrogen, and nitrogen, are derived; and from the various saline ingredients of the soil, those inorganic substances which are essential to the growth and well-being of mankind and of the lower animals are readily abstracted by the absorbent fibres of the roots. Thus formed, plants constitute the source from which all living beings obtain the nourishment which is necessary to their existence, and of which the very substance of their bodies is composed; an arrangement which is most strikingly evident in the herbivora, because vegetables are their only food, but not less certainly in the carnivora, since the animal flesh which they consume is either that of the herbivora or of some animals which have fed upon them.

It is impossible not to admire the simplicity which pervades the whole of this vast scheme, in which we find so large a portion of the animal body composed of materials almost identical in composition, though differing so essentially in their use and applications. If one of these principles, albumen or casein for instance, be contained in the food in quantity insufficient for the requirements of the animal, it is readily supplied from one of the others by the addition or removal of a minute quantity of sulphur or phosphorus, both of which are always present; whereas, if this beautiful provision had not been made, a large amount of disease and suffering would have almost necessarily ensued. Moreover, had the task of elaborating these highly complex principles from more simple ingredients devolved on animals themselves, much complicated machinery would probably have been required, which would have added unnecessarily to the complexity of the body, and consequently to the sources of physical derangement.

[Since the above has been in type, some researches, which are still in progress, have thrown a doubt upon the exact composition of protein, and indeed rendered it uncertain whether it can be obtained in a state perfectly free from sulphur.]

Bibliography. — The following books may be mentioned as containing the fullest descriptions of protein and its compounds, together with other branches of physiological chemistry:—*Simon*, Handbuch der angewandten medizinischen Chemie, of which a translation has been published by the Sydenham Society. *Liebig*, Traité de Chimie organique, tom. i. & iii. *Liebig's* Animal Chemistry, translated by Gregory. *Mulder*, Chemistry of vegetable and animal physiology, translated from the Dutch by Fromberg; and *Dumas*, Traité de Chimie appliquée aux arts, tom. vii. & viii. Besides these many detached papers of great value will be found in the later volumes of the Annales de Chimie et de Physique; Annalen der Chemie und Pharmacie, by *Liebig* and *Wohler; Poggendorff's* Annalen der Physik und Chemie; Philosophical Transactions, Philosophical Magazine, &c.

(*J. E. Bowman.*)

PTEROPODA (Gr. πτερον, a wing, πους, a foot; Fr. *Pteropodes;* Lat. *Mollusca pinnata*).—An order of Molluscous animals established by Cuvier, and named in accordance with his arrangement of the Molluscous division of the animal kingdom, from the position of their organs of locomotion, which in the creatures we are about to examine is very remarkable. All the animals belonging to the order are marine, and in some regions of the ocean crowd the surface of the sea at certain seasons in immense numbers, swimming by the aid of two muscular expansions resembling fins, which are attached to the opposite sides of the neck, and serve as paddles, although, in the language of Natural History, named feet.

Notwithstanding the multitudes of individuals belonging to this group, which are said to swarm both in the polar regions and in tropical climes, the number of genera at present ascertained to exist is very limited, and such is their minute size and the delicacy of their structure, which precludes the possibility of studying them, unless in a fresh state, that, up to a very recent period, their anatomy was imperfectly understood, and, doubtless, much remains yet to be achieved by those who may be favourably situated or investigating them more closely.

The characters which they present in common, and by which they are separated by naturalists as a distinct group of Mollusca, are the following: — Their bodies are free, and organized for natation; they are furnished with a distinct head, but possess no locomotive organs, except a pair of lateral fins.

Genera.

Clio (*fig.* 108).
Hyalea (*fig.* 114).
Pneumoderma (*fig.* 115).
Cymbulia.
Limacina.
Cleodora.
Atlanta.

M. d'Orbigny, in a memoir read before the Academy of Sciences in Paris*, gives some interesting particulars relative to the organization and habits of this remarkable class of molluscous animals. They are met with in all seas, under the equator as well as in the

* *Vide* Ann. des Sciences Nat. for 1835, p. 189.

vicinity of the polar circle; and, being eminently constructed for a pelagic life, never approach the shore. They are all, moreover, nocturnal or crepuscular, voyagers agreeing that they are never to be seen during a clear day when the sun shines brightly; but towards five o'clock in the evening, when the weather is cloudy, two or three species begin to make their appearance at the surface of the water, generally belonging to the genus Hyalea.

As soon as twilight begins, large quantities of small *Cleodoræ*, *Hyaleæ*, and *Atlantæ* may be caught; but the larger species only come to the top when night has set in; at which time only the *Pneumodermas*, the *Clios*, and the large *Cleodoræ* can be procured. Certain species indeed only approach the surface on very dark nights, as, for example, the *Hyalea balantium*. Very soon all the smaller species again gradually disappear, as do the large ones a little later, and towards midnight a few stragglers only of different kinds are to be met with. At sunrise not a single Pteropod is to be seen, either at the surface, or at any depth to which the eye can penetrate. Each species, in fact, seems to have its appropriate hours, or rather its appropriate degrees, of darkness.

M. d'Orbigny supposes, from these habits, that each species lives at a certain depth in the water which is proper to it, and where it is consequently exposed to a diminution of light proportionate to its distance from the surface. Every species, therefore, will only come to the top at that period of the twenty-four hours when the obscurity approximates to that to which it is accustomed in its usual situation while the sun is above the horizon, mounting gradually upwards as the light of day diminishes. If the Pteropoda remained all night at the surface of the sea, there might be reason to think, as M. Rang supposed, that they ascend at sunset for the purpose of obtaining food or fresh air in the most superficial strata of the ocean; but as these could be procured at all hours, it seems more probable that it is the light which thus regulates their movements.

There is reason to suppose that each species of Pteropod remains during the whole year in the same regions of the ocean. These regions are of different degrees of extent, and currents doubtless tend to enlarge their boundaries; probably to this cause must be attributed the extensive diffusion of certain species met with in all climates; whilst others of larger size are only found in the torrid zone, and others again of equal dimensions are peculiar to cold climates.

A table appended to the Memoir of M. d'Orbigny assigns the limits between which each species has been found, and its nocturnal or crepuscular habits. From this table it appears, that of twenty-nine species of Pteropods known to the author, fourteen are met with both in the Atlantic and Pacific oceans, whilst eleven are proper to the Atlantic and four to the Pacific; of these seventeen are altogether nocturnal in their habits, and only eleven crepuscular.

The Pteropoda swim in a very peculiar manner. Their cephalic fins are only able to support them by a constant repetition of rapid movements, resembling those of the wings of a butterfly. These fins are kept in motion continually; and, according to the direction of their stroke, the animal advances horizontally, or mounts or descends, the body remaining all the time either in a vertical position or slightly inclined. Sometimes they keep spinning round without changing their place, or even keep at a certain height in the water without any apparent exertion; but this power of remaining motionless has only been observed in a small number of species, the butterfly-movement of the wings being most commonly resorted to. If while they are thus in motion, the appearance of any strange body or even a sudden shock given to the vessel in which they are contained, causes them alarm; their wings fold upon their bodies, or in some species are entirely withdrawn into their shell, and the animal sinks rapidly to the bottom of the vessel. Most probably, when at liberty, as soon as the creature has sunk to a sufficient depth to ensure safety, it again unfolds its wings, and sustains itself in the water instead of allowing itself to go quite to the bottom.

The Hyalea and Cleodora swim with the greatest rapidity, in Pneumoderma and Clio the movements are less vivacious.

The larger Pteropods seem to feed principally upon smaller species of their own class, as well as upon the minute crustaceans that swarm in the seas they frequent.

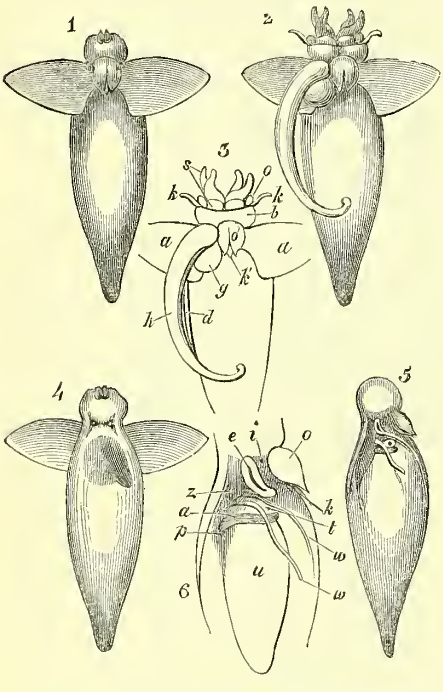
Clio. *Integument.* — The skin of the Clio is not smooth, but studded with numerous little wart-like eminences, causing a roughness, which is in direct relation with the red colour of the integument, and is consequently most conspicuous near the extremity of the tail. Both the roughness and the red colour indeed are produced by the presence of a multitude of little cavities or sacculi filled with an oily red pigment, the pointed ducts of which project externally. These pigment-sacs are not only most abundant near the extremity of the tail, but in that part of the body are of larger size than elsewhere: they are all flask-shaped, opening upon the surface of the body by a narrow neck, while their larger extremity is imbedded in the subcutaneous cellular tissue. Beneath these larger pigment-sacs smaller ones of a similar description are perceptible, much smaller in their dimensions than the preceding, and in many places where the larger ones are deficient, the smaller pigment cells are proportionately more numerous: both kinds are filled with the same oil-like colouring material, and are apparently comparable to simple mucous follicles, only their secretion is of a more oily character.

With the exception of the pigment cells, the integument of the living Clio is quite transparent, but after being kept in spirits of wine, its transparency is considerably diminished; in its

substance, muscular fasciculi are perceptible, the direction of which is principally towards the crucial muscles of the fins. Upon the dorsal region of the body, these tegumentary muscles first become distinct at the transverse constrictions above referred to. These constrictions disappear as soon as the skin is cut through, and the inner layers of the dorsal region then appear quite lax. In this way, indeed, the existence of transverse fasciculi of cutaneous muscles is rendered evident, even when their presence cannot be proved by direct observation.

In many places, the cutaneous muscles are still more complex in their arrangement, more particularly in the neighbourhood of the eyes. In the head, and partially also in the neck, where a firmer connexion between the skin and the general muscular strata of the body exists, an expansion of the proper cutaneous muscles is with difficulty to be demonstrated.

Fig. 108 (1 to 6).



1. *Clio Borealis*, seen from the ventral aspect, the head-cowls shut together.
2. The same; the head-cowls turned back, and the cephalic and generative apparatus displayed.
3. Details of ditto.
4. Clio borealis with the head cowls closed, seen from the dorsal aspect.
5. Side view (right) of the same, the fins cut off at their roots.
6. Details of ditto. (*After Eschricht.*)

The nerves of the integument are easily traced in fresh specimens on account of the transparency of the skin. The most conspicuous are two large cutaneous nerves running on each side of the body, which ramify upon its lateral and ventral aspects.

Immediately beneath the skin is a layer of cellular tissue, which is very different in different regions. In the hinder part of the body it exists in great abundance, and in it, as already stated, the large pigment cells are imbedded, so that in this region the skin is very easily separated from the muscular strata beneath. It is most abundant likewise in the region of the heart where the urinary bladder is situated. In the fins, this cellular membrane is more scanty, and in the regions of the neck and head, it is so dense that here the skin can only be raised with difficulty. In specimens that have been kept in spirits, the subcutaneous cellular tissue is very generally infiltrated with fluid so as to give the appearance of a cavity existing beneath the integument, the boundaries of which are circumscribed by those parts where the skin is most adherent to the subjacent tissues, or where the cutaneous muscles interlace with each other.

Muscular system. — The muscles of the Clio borealis are chiefly disposed in a single layer, situated beneath the subcutaneous cellular tissue, that encloses the whole hinder part of the body as in a bag, which, however, in the region of the neck and of the head, spreads out into separate fasciculi of muscle. This muscular bag is described by Cuvier* as being composed of very conspicuous longitudinal fibres, derived from two principal fasciculi attached to the sides of the neck, the effect of which will be to shorten the whole body, and make it assume a form approximating to the spherical. In fresh specimens preserved in spirits, the muscular bag in question is easily visible through the skin; but in the living animal, it is most likely itself transparent, and in old specimens cannot be seen on account of the opacity of the external integument. The muscular fibres composing this sheath, do not by any means run straight and undivided from behind forward, but, on the contrary, interlace with each other, so as to form an expansion in which the longitudinal fibres are the most conspicuous. From the neck forwards, these muscular bands become more precise in their arrangement. At the sides of the body, they separate from each other so as to leave a space both behind and in front, in which the muscular layer is deficient; the dorsal and ventral fasciculi becoming more and more detached as they advance forwards, leaving a wide opening in the muscular sheath, which near the head gives passage to the lateral fin, and behind this for the pair of large cutaneous nerves, also on the right side, close to the fin, for the common opening of the male and female generative apparatus, and, a little behind the exit of the two cutaneous nerves, for the anus. In its posterior corner lies the pericardium also on the right side but more deeply situated.

These different parts, as they issue through the muscular opening of the right side, are further embraced by muscular fasciculi, which

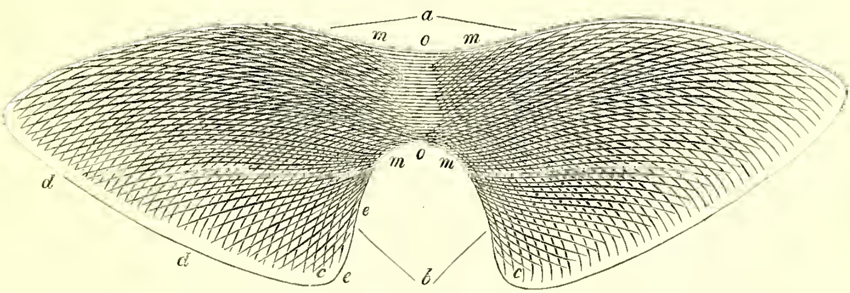
* Mémoire sur le Clio, p. 6.

run transversely from the dorsal to the ventral aspect of the body bounding and separating their orifices.

Locomotive Apparatus.—The locomotive apparatus of the Pteropoda is constructed upon most peculiar principles, consisting of a pair of fin-like expansions attached to each side of the neck of the animal.

These fins, or, as they are commonly called, *wings* in the Clio have a very remarkable structure, the two being continuous with each other, through the intervention of a central part, which extends transversely across the neck of the animal, so that the lateral expansions are only the free extremities of the same organ, the whole apparatus representing, with curious exactness, the double paddle used by the Greenlanders in navigating their light double-pointed canoes (*Kajaks*). The entire apparatus is muscular, and consists of two layers, precisely similar in their structure, which, at their margins, overlie each other, but are only connected together by means of cellular tissue. The course of the muscular fibres is shown in the annexed figure, representing the whole of the swimming apparatus removed from the body; in which the following parts may be distinguished : — *a*, the anterior or dorsal margin; *b*, the posterior or ventral excavation; *c c*, the posterior, transparent, triangular lappets which bound the fin ; *d d*, the posterior outer border ; *e e*, the posterior inner border ; *o*, the central portion which traverses the neck ; *m m m m*, commencement of the free portions of the fins.

Fig. 109.



Clio Borealis.

Swimming apparatus detached. (*After Eschricht.*)

In the cellular membrane interposed between the two muscular layers of the fin apparatus, four or five large nerves are seen to run a tortuous course, and to divide into innumerable fibrillæ. Eschricht likewise observed a considerable blood-vessel derived from the ventricle of the heart (*not from the auricle*), mounting up and dividing to supply each fin.

Respiration and Circulation. — According to Cuvier's views the fins of the Pteropoda have been very generally regarded as performing likewise the functions of branchiæ. "Their surfaces, seen with the microscope, present a net-work of vessels, so regular, so close, and so delicate that it is impossible to doubt their office : their connection with the internal vessels and the heart, moreover, confirms this idea."* Cuvier's opportunities of investigating this point of their anatomy were, however, very limited ; a single specimen only, and that long kept in spirits of wine, having been at his disposal. Eschricht's researches do not at all confirm this view of their nature; and it appears clear that Cuvier mistook the network of muscular fibres represented in the preceding figure for vascular ramifications. The vessel likewise called by Cuvier "the branchial vein," and which he regarded as returning the blood from the branchiæ to the auricle of the heart, Eschricht assures us, does not communicate with the auricle, but is derived from the apex of the ventricle so as to be evidently arterial, and not venous, in its nature.

With regard to the connexion which exists between the fin-apparatus and the body of the Clio, it would appear that its central muscular basis passes directly through the neck, and is only attached to the surrounding parts by nerves, vessels, skin, and cellular membrane.

Nervous system.—The nerves of the Clio are very easily traced, seeing that they are not only of considerable size, but are likewise conspicuous, on account of their pale red colour, at least while the specimens are tolerably fresh.

The œsophageal ring lies in the neck above the centre of the fin-apparatus, and lodged in its dorsal excavation. It is composed of eight large and two small ganglia. Each ganglion is surrounded by a transparent investment, and is very evidently composed partly of a reddish and partly of a white nervous substance. Of the eight larger ganglia of the circum-œsophageal ring the two anterior (*fig.* 113. 30, 1) are situated close together, upon the dorsal aspect of the œsophagus ; the two posterior (*fig.* 113. 30, 4) are likewise close together, but beneath the œsophageal tube. Of the four intermediate ganglia, two are situated close together on each side of the œsophagus (*fig.* 113. 30, 2, 3), so that when viewed

* Cuvier, Mém. sur le Clio.

superficially, either from the dorsal or ventral aspect, they have the appearance of forming one elongated mass. By means of a nervous band which connects them, the eight ganglia form a double ring, seeing that the two lateral pairs of ganglia are, as well as the inferior, brought into communication with each other through the intervention of a cross branch which runs beneath the œsophagus.

In addition to the eight ganglia above mentioned there are likewise two small nervous masses (*fig.* 113. 30, 5), situated one on each side of the anterior pair, with which they are connected by short nervous branches.

All the nerves given off from these centres seem to proceed from the ganglia nearest to their place of destination. From the anterior pair are derived all the nerves supplying the parts of the head and the eyes. From the lateral pairs the nerves of the fins are principally given off, while the posterior pair furnishes nerves to all the hinder parts of the body.

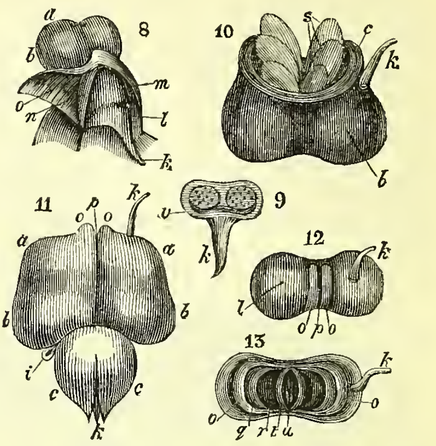
Eyes.—The eyes in Clio are situated upon the dorsal aspect of the body, in the constriction which constitutes the neck. In this situation the skin is drawn deeply around them, so that they seem to be lodged in special depressions appropriated to receive them. Each eye (*fig.* 113. 31) has somewhat the shape of a bent cylinder, the two ends of which are of a spherical form. The external spherical extremity of this eye, which is transparent, and constitutes the cornea, stands prominently above the level of the skin. By transmitted light it is not difficult to distinguish the construction of the interior. The middle third of the cylinder is generally of a dark colour, whilst the anterior and posterior extremities of the cylinder are comparatively transparent; but, probably, in the recent animal, the dark pigment extends back as far as the hinder end—anteriorly, it is easy to perceive the existence of a transparent lens; but from the small size of the organ, it is difficult to make out their structure more completely. In connexion with these eyes, delicate muscular fasciculi may be traced radiating in different directions, which would seem to have the office of turning the eye-ball towards any particular object.

The only other special organs of sensation possessed by the Clio are the tentacula; but these will be best described in connexion with the head to which they are appended.

Head-cowls and Tentacula.—The structure of the head of Clio is very remarkable; and, in its general characters, cannot be more appropriately described than in the words of Pallas.* "Caput contractum subgloboso-didymum est, lobo vel utroque vel alterutro, imo quandoque neutro, antice papillâ carneâ (*tentaculum*) acutâ, mucronatâ. Qui lobi sunt proprie præputia duo (*the head-cowls*) crassa, carnea; hemisphærica, contractilia, basi coadunata, e quorum interiore latere emergunt tentacula (*head-cones*) tria carnosa, conica, æqualia quæ ori utrinque adstant et contracta in præputio tota delitescunt."

* Spicelegia, x. p. 28.

Fig. 110 (8 to 13).



Anatomy of Clio.

9. Transverse section of the ventral fasciculi, as they pass through the nerve surrounded by the muscular collar (v).

10. Head of Clio, with the cowls half expanded, showing the conical cephalic appendages (s), and one of the tentacula (k) protruded.

11. Head of Clio, cowls closed, and the left tentacle protruded.

12. The same seen from above.

13. The same, the cowls being widely separated so as to display the opening of the mouth.

(*After Eschricht.*)

The above description will, however, be better understood by a reference to the accompanying figures, in which the structures above mentioned are delineated on a large scale. In *fig.* 110. 11 the head is represented, seen from the ventral aspect with the head-cowls (a, b) closed together, concealing all the other organs except the tentacula, one of which (k) is seen protruding through an opening in the left cowl, that of the opposite side being retracted—while in *fig.* 110. 10 the head-cowls are shown partially folded back, so as to display the conical appendages (head-cones) which the cowls enclose and protect.

Each of the cowls (*lobi*, Pallas; *buccæ*, Fabricius) seems, when more closely examined, to be composed of two spherical parts intimately conjoined, of which the anterior (*fig.* 110. 11, $a\ a$) is the smaller, and the posterior ($b\ b$) the larger. The posterior spherical portions are continuous with each other; they enclose a large cavity, which is, in its widest part, filled up by the penis; but, in its narrower and median part, contains the parts of the mouth—the œsophagus and the salivary apparatus. The smaller or anterior spheres, on the contrary, are only produced by the folding of the skin over the head-cones, and disappear when these organs are protruded. In the fore part of each of the anterior spherical portions of the cowl is a little flat surface, in the middle of which may be observed

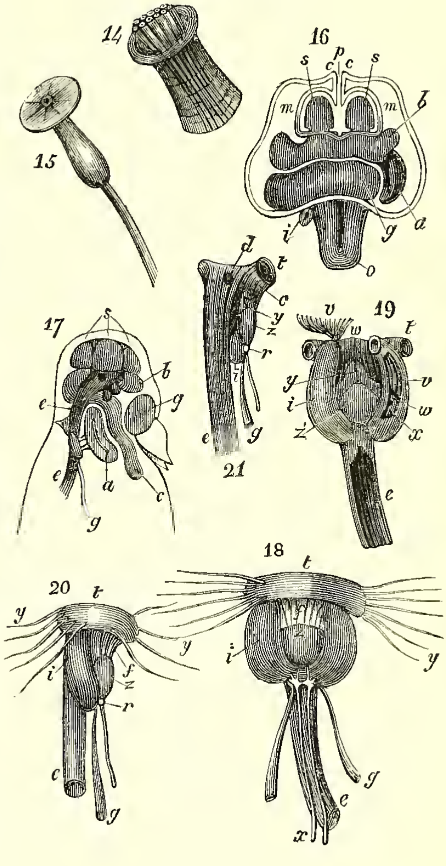
either the tentacle (*fig.* 110. 10 and 11, *k*), or the orifice (*fig.* 110. 12, *l*), through which it is protruded : the two flat surfaces are separated from each other when the cowls are closed by a longitudinal fissure (*p*), the margins of which form two prominent lips (*o o*).

The lateral tentacles (*k*) are cylindrical, smooth, and terminated by rounded extremities. They are hollow, and in their interior, three longitudinal bands of muscle and a nerve of considerable size are distinguishable, so that they can be retracted in the same manner as the horns of a snail, nothing remaining externally to indicate their position, except the hole through which they are protruded. When thus inverted the tentacles are found lodged in the cavity of the head, with their apices directed inwards.

The two smaller spheres of the hood or cowl are separated from each other by the longitudinal fissure (*fig.* 110. 11), which Fabricius, very inappropriately, called the *mouth*, although, at the same time, he was acquainted with the real mouth, and recognised it as such. This vertical fissure occupies the entire top of the head, and is continued for some distance both on its upper and under surface, or, more properly speaking, the real head is buried deeply in the interspace between the two cowls, and when these are separated from each other, the following parts are seen situated between them : in the centre of the floor of the fissure is the vertical opening of the mouth (*fig.* 110. 13, *u*), between which and the borders of the hood (*q*), are the crescentic spaces (*r*), in which are situated the conical appendages to the head already mentioned, and which are represented protruding from between the margins of the hood in *fig.* 110. 10 (*s*).

Conical Appendages to the Head. — The conical appendages to the head (Kopfkegel, *Eschricht*), when fully expanded, form a kind of star round the mouth (*fig.* 108. 3, *s*), and were erroneously styled by Fabricius "soft teeth" ("suntque dentes hi molles subcrustacei"). It is to Eschricht we are indebted for a knowledge of the real nature of these wonderful organs, the structure of which is unparalleled in the animal creation. It has been already noticed that these conical bodies are of a red colour in the recent animal, and, when they are protruded, it is easily discoverable with a lens that this colour depends on the presence of numerous separate coloured points distributed over their surface. When still further magnified, these points show themselves as closely aggregated spots, arranged with great regularity upon the exterior of the cone. Upon a rough calculation there may be about three thousand of these spots upon each conical appendage, each of which, when closely examined, under favourable circumstances, assumes very much the appearance of the polype-cell of one of the Sertularian polypes, and exhibits a structure which is truly admirable. Each little spot consists, in fact, of a transparent sheath, enclosing a central body, composed of a stem terminated by a kind of tuft, which last can be protruded at times beyond the margin of the sheath. When viewed laterally (*fig.* 111. 14) it is apparent that this central body consists of several filaments or tubes, every one of which expands at its extremity into a dilated portion, terminated by a little disc (*fig.* 111. 15), and about twenty of these are enclosed in each sheath. The conical appendages to the head of a single Clio are, therefore, furnished with ($20 \times 3000 \times 6$) about three hundred and sixty thousand of the stem-supported discs in question.

Fig. 111 (14 to 21).



Clio Borealis.

14. One of the 3000 prehensile organs with which each of the six conical appendages to the head is furnished. Magnified 300 diameters.

15. An isolated sucking disc from the above. Magnified 900 diameters.

16. The head and neck laid open by a longitudinal section, showing two of the conical appendages and the penis, in situ. Magnified 5 diameters.

17. Longitudinal section of the head along the mesial line.

18. to 21. Pharynx and oral apparatus. Magnified 7 diameters. (*After Eschricht.*)

As relates to the internal structure of these conical organs, Eschricht ascertained that they

are hollow, and that their cavities communicate with the common cavity of the head: they have likewise their proper muscles, and each receives a large nerve derived immediately from the anterior supra-œsophageal ganglion. As to the use of this elaborate apparatus, there is still room for speculation. Captain Holböll, although he frequently observed them porrected, while the creature was swimming, never saw them employed as suckers or instruments of prehension; nevertheless, it seems impossible to doubt that such is their real office, when we reflect upon their remarkable structure, and further take into account their situation, so completely analogous to that occupied by the sucking discs of the Cephalopoda, and still more closely resembling the cephalic appendages of *Pneumoderma*. It is, therefore, extremely probable that these organs are employed for holding to foreign objects at the bottom of the sea, and that the great number of the sucking discs is in correspondence with the power possessed by the Clio of crawling about upon uneven surfaces.

The mouth of the Clio is a vertical fissure, that is easily displayed by slightly folding back the head-cones (*fig.* 110. 13, *u*). Its margins seem to enclose some calcareous substance, which, in specimens preserved in spirit, is of a chalky whiteness. Numerous muscular fasciculi surround this opening, which, when expanded, has somewhat of a triangular form, so that during life the mouth can be forcibly opened by the radiating muscular fasciculi that surround it.

In the cavity of the mouth there may be observed, on each side, a round fossa, in which can be seen projecting, even with the naked eye, a hard shining substance, first noticed by Pallas and Fabricius, who regarded these bodies as simple teeth. Closer inspection, however, reveals them to have a very curious structure, which is, perhaps, unique, each consisting of a bundle of about thirty gold-coloured, crooked, stiff and sharp hooks (*fig.* 112. 22, *w*), derived from a common base (*x*), and forming a pair of lateral jaws, wherewith the creature seizes its food.

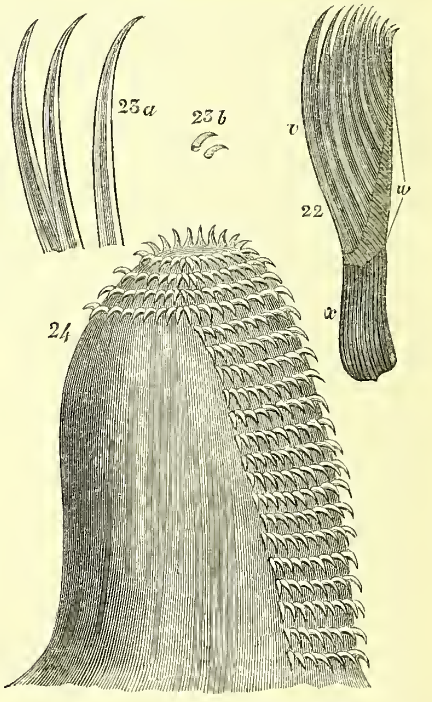
In the middle of the ventral aspect of the cavity of the mouth there is, moreover, a prominent tongue-shaped organ, which, when moderately magnified, may be seen to consist of two lateral bands of a black colour, which are united in the middle line, and which are covered with an immense number of extremely minute teeth, that will be more particularly described hereafter. The pharynx, when examined from above, is somewhat lyre-shaped: it is composed of two lateral branches (*fig.* 111. 19, *i*), the posterior ends of which are joined by a convex central portion (*z*). The tube of the œsophagus is not prolonged immediately from its hinder extremity, but seems to arise from the hinder wall of the pharyngeal cavity (*fig.* 111. 17 and 21, *e*).

The nerves of the pharynx arise from two ganglia (*fig.* 111. 18, 20, *y*) situated immediately behind it, in conjunction with the anterior ganglia of the circumœsophageal ring, and which inferiorly are connected together by strong branches of intercommunication and from which nerves radiate laterally to supply the surrounding parts. The thin ducts of the salivary glands (*fig.* 111. 17, 18, 19, and 20, *g*) terminate above these ganglia opening into the cavity of the mouth in the immediate vicinity of the tongue.

The pharynx, when viewed with a lens, and still more when examined under the microscope, resembles, very closely, the gizzard of a gallinaceous bird, the resemblance consisting in the great strength of its muscular parietes.

Each lateral portion (*fig.* 111. 18, *i*) is a small curved cylinder, the outer wall of which is entirely muscular. The fasciculi are principally arranged in two layers, the fibres crossing each other. On opening one of these muscular capsules, by means of a fine pair of scissors it is found to contain, in its interior, a cylindrical body made up of several parts. At its anterior extremity are situated the lateral teeth above alluded to (*fig.* 111. 19, and *fig.* 112. 22, *v*). These are arranged in parallel arches, in such a way that their points all attain the same height, notwithstanding the great difference in their length, the posterior (*exterior*) tooth (*fig.* 112. 23, *a*) being far the longest; while the an-

Fig. 112 (22 to 24).



Clio Borealis.

22, 23 *a*, 23 *b*. Dental apparatus, magnified 28 diameters.

24. Lateral view of the free portion of the tongue, magnified 130 diameters. (*After Eschricht.*)

terior (*interior*) (23, *b*) is the shortest of the series. The stem upon which these are fixed (22, *w*) is sloped off in the same proportion, and has a somewhat triangular shape. When crushed under the microscope, it is found to consist entirely of muscular fibres arranged with considerable regularity, and principally disposed in two opposite directions, so that they cross each other; and doubtless a part of their office is to raise and depress the individual teeth, implanted upon the common stem. The hinder portion of the cylinders (*x*) containing this extraordinary dental apparatus, is muscular, and composed of longitudinal fasciculi, by the aid of which the stems that support the teeth are retracted, their protrusion being effected apparently by the construction of the capsules themselves. The manner in which the Clio makes use of these teeth may, therefore, be inferred from their anatomical arrangement. The cylinders wherein they are lodged are so much bent (*fig.* 111. 18, 19, *i*), that when the two dental organs of the opposite sides are protruded the apices of the teeth with which they are armed must meet together outside the mouth, and when in this condition the teeth of each organ are widely separated and spread out, they will form, as it were, a couple of long combs (19, *v*), and evidently perform the functions of a pair of tenacious jaws.

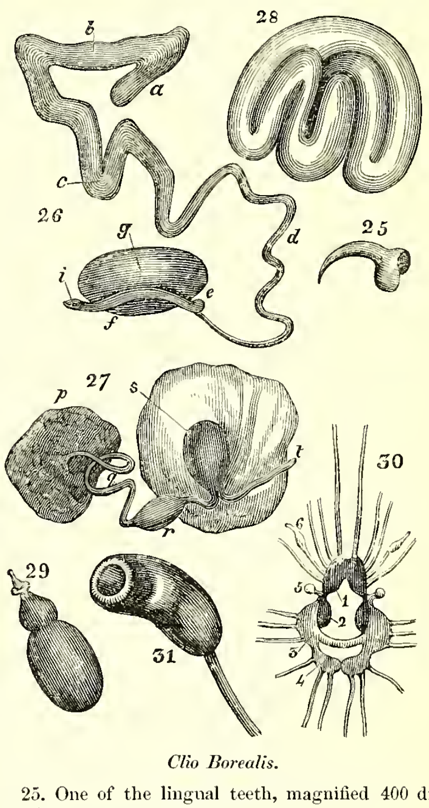
The tongue may be divided into two portions; the one free, and the other fixed, studded with a number of hooklets that can scarcely be estimated at fewer than from six to eight hundred, the disposition of which at once indicates their office to be to facilitate the propulsion of the food into the œsophagus, as is the case in the Cephalopods and various other Mollusca.

The œsophagus is, for the greater part of its length, surrounded by the two salivary glands, which extend quite into the abdominal cavity, where they are connected to each other, and to the liver by lax cellular membrane. The stomach is a mere dilation of the œsophagus, and is entirely embedded in the substance of the liver. The latter organ appears, when examined superficially, to be entirely made up of a multitude of *Acini*, each of which contains within it a cavity that communicates through a wide aperture with the interior of the stomach; and hence it results, that, although the exterior of the liver is seemingly composed of large granules, the walls of the stomach are perforated all over with openings, leading into blind cavities, so as to have a completely cellular appearance.

The intestine is a simple tube, passing straight from the termination of the stomachal portion of the alimentary canal to the anal orifice, which is situated on the right side of the neck immediately behind the corresponding fin.

The course of the circulation in the Pteropoda has not been as yet completely made out. In the Clio borealis, the heart enclosed in its pericardium is situated on the right side of the posterior end of the abdominal cavity just at the point where the dorsal and ventral bands of muscle separate to form the wide lateral opening. The pericardium is pointed in front and broad behind: its walls are thin and transparent, but at the same time very strong. On opening the pericardium, the ventricle of the heart is seen to have the shape of a triangular pyramid with rounded angles, the apex of the pyramid being directed towards the head, whilst its base is turned towards the hind part of the body. From the apex of the heart arises a large vessel, which immediately pierces the pericardium, and supplies branches to the liver and to the internal organs of generation; it then advances forward, and supplies the parts about the neck, more especially the lateral fins, and most probably is ultimately distributed to the head and its appendages. This vessel is evidently the aorta.

Fig. 113 (25 to 31).



Clio Borealis.

25. One of the lingual teeth, magnified 400 diameters.
26. Male generative apparatus, removed from the body and unfolded.
27. Female generative organs displayed.
28. Convex surface of the testes.
29. One of the pigment sacs of the integument, magnified 120 diameters.
30. Nervous system, magnified 12 diameters.
31. One of the eyes, magnified 40 diameters. (*After Eschricht.*)

Generative system.— The reproductive organs in the Clio borealis occupy a very considerable portion of the abdominal cavity.

They consist, first, of an *Ovary* with its *oviduct;* secondly of the "*bladder;*" and, thirdly, of the *testis,* upon which the bladder rests.

The *ovary* (*fig.* 113. 27, *p*) is closely connected with the liver, in conjunction with which it occupies the dorsal region of the abdominal cavity, its anterior part being filled with the voluminous testicle. The ovary itself is nearly of a hemispherical shape, and is of a pale red colour, its surface having a granular appearance. When crushed under the microscope, all the granules of which it consists exhibit in their interior a little vesicle, together with a dark spot; the former being, doubtless, the vesicle of Purkinje, the latter the germinal spot of Wagner.

The oviduct (*q*) is tolerably thick, and arises from the middle of the flat surface of the ovary; it immediately becomes considerably convoluted, so that it usually forms two loops, and, gradually becoming attenuated, reaches the "bladder" (*s*), which is situated in immediate contact with the testicle; but, before joining the latter, it generally swells into a dilatation (*r*); but this dilatation is not constant; for sometimes Eschricht found two such enlargements; whilst in other instances the oviduct retained the same diameter throughout its entire length: when present, the swelling was found to be solid, and probably was produced by an accumulation of ova, coagulated by the action of the spirit in which the specimens had been preserved.

The "bladder" (*s*) is situated very close to the surface of the testis, and appears to be supported upon a furcate stem, through the intervention of which it is partly in communication with the oviduct, and partly with the testicle. This "bladder" is somewhat larger than the accidental swellings of the oviduct alluded to above, but, like them, was found to be solid; and sometimes the mass was divisible into two flattened halves, a circumstance that would seem to indicate the non-existence of any cavity in the interior.

The testis itself, in a recent specimen, is so large as to occupy a very considerable part of the abdominal cavity: it is nearly transparent; and when portions of it are examined under the microscope, its substance seems to be entirely made up of minute tubes, connected together by delicate membranous processes. Its external convex surface (*fig.* 113. 28) is convoluted, so as to give it the appearance of being a hollow vesicle three times folded upon itself; whilst its inferior concave surface exhibits under the microscope a reticulate appearance, something like that of the stomach of a ruminant quadruped.

The common outlet of the ovary, of the bladder, and of the testicle is short, but tolerably thick. It mounts upwards, and terminates close behind the right fin, in the immediate vicinity of the anal orifice.

On opening the cavity of the head, by removing its anterior wall (including the collar and the subjacent muscular layer), its contents are displayed as exhibited in *fig.* 111. 16. Immediately behind the contracted conical appendages, and close to their hollow bases, is seen a long milk-white organ (*b*), which, in old specimens, is so extremely brittle, that it is generally broken in the dissection. Behind this, and close to the collar, lies a red sacculus not easily to be displayed; and, in the neck itself, immediately upon the collar, is situated a single loop, formed of the same white substance as *b*.

On carefully unfolding these parts, they are found to present the structure displayed in *fig.* 113. 26, the transverse body (*b*) and the loop (*c*) constituting portions of the same viscus. The transverse portion is a canal terminating by a blind extremity (*a*), while the loop itself may be displayed as an extremely attenuated canal (*d*) of a reddish colour, which, after several convolutions, opens into the red sacculus (*g*), and ultimately terminates in another short, but wider, tube (*f*); the common orifice of the sacculus and of the convoluted canal is a wide, longitudinal opening, situated in the cavity between the right fin, the head, and the collar. On cutting into this canal, it is found that the milky colour it presents is but slightly owing to the nature of its contents, depending principally upon the texture of its walls, which, when examined under the microscope, are found to contain numerous granular bodies, which are apparently of a glandular character, united together by a very thin and transparent membrane, the delicacy of which readily accounts for the fragility of the tube.

The structure of the red sacculus (*g*) is not yet fully understood. Its walls are in some parts very thin, and on opening it, the tube (*f*) is seen to be continued through it.

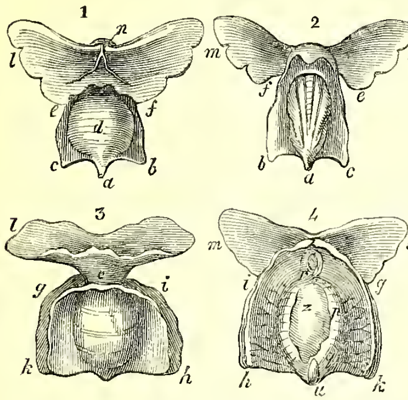
Eschricht was, at first, in considerable doubt as to the nature of this remarkable apparatus: he observed, however, that in several specimens, a portion of the sacculus was inverted and protruded externally in the shape of a long bow-shaped organ (*fig.* 114. 3, *h*), along the cavity of which a delicate canal could be distinctly traced, the bow-shaped organ being manifestly the penis, everted in the same way as in many Gasteropod Mollusks, and the delicate canal constituting the vas deferens.

Hyalea. — The two fins are supported upon a fleshy neck, enclosed between the two lobes of the mantle (*fig.* 114. 3, *c*), which latter (*fig.* 114. 3, *g*, *h*, *i*, *k*) correspond accurately with the valves of the shell, beyond the edges of which they protrude all around, and which they cover with a thin epidermis.

The position of the branchiæ Cuvier observed not to correspond with what he had, erroneously, believed it to be in Clio,—namely, the surface of the lateral fins; for in Hyalea he could not discover any vascular net-work in those organs, even with a microscope; and thus indirectly confirms the correctness of Eschricht's views upon this point. He, therefore, sought for them elsewhere, and, "on breaking the shell, he found them to be situated between the two lobes of the mantle at the bottom of the outer space between them

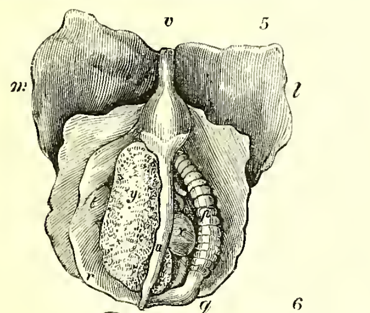
on each side, so that the lateral fissures of the shell have apparently the function of admitting the surrounding element to the branchial organs. These latter are composed of little laminæ, resembling those of patellæ, phyllidia, &c., which surround the body so as to form a sort of elliptical belt, not placed transversely, but parallel to the course of the dorsal surface (*fig.* 114. 5, 6. *p*, *q*, *r*, *s*). The

Fig. 114 (1 to 9).



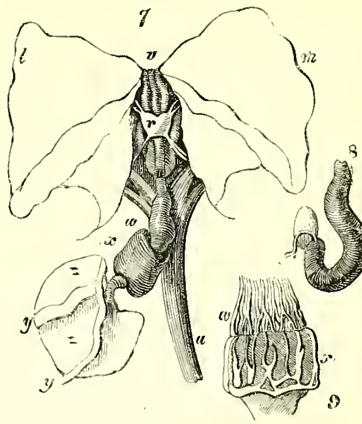
Anatomy of Hyalea. (*After Cuvier.*)

1. The animal entire, with its shell, viewed from the side of the inflated valve.
2. The same seen from the side of the flat valve.
3. The Hyalea deprived of its shell, the lobes of the mantle drawn aside and expanded, from the inflated side.
4. The same from the flat side, in which part of the viscera may be observed through the membrane of the mantle, as also the muscular fibre of the latter.



5. The animal slightly magnified, with the mantle opened from the flat side, showing the retractor muscle and the viscera in situ.
6. The same, with the viscera displayed.

7. The same, seen from the opposite aspect: the integument of the neck has been divided as far as the mouth, showing the respective positions of the brain, of the œsophagus, of the penis, and the tongue; like terminations of the retractor muscle.



8. The penis detached.
The crop and gizzard laid open.
The same references apply to all the figures.
a, *b*, *c*, prominent points of shell; *d*, inflated valve; *e*, *f*, lateral margins of the shell; *g*, *h*, *i*, *k*, margins of mantle; *l*, *m*, cervical fins; *n*, mouth; *o*, neck; *p*, *q*, *r*, *s*, branchiæ; *t*, position of the heart; *u*, retractor muscle; *v*, *v*, œsophagus; *w*, crop; *x*, gizzard; *y*, intestine; *z*, liver; *α*, ovary; *β*, testicle; *γ*, supra-œsophageal ganglion.

other viscera occupy the arched and rounded portion of the shell, or the interior of the cervical region, and are enveloped in a kind of peritoneum of a blackish colour. On placing the animal upon its flat valve, or ventral surface, the heart is seen to be situated on the right side, at the inner border of that portion of the branchial band marked *t* in *fig.* 114. 5. A cylindrical muscle (*u*, *fig.* 114. 5 and 7) is attached to the intermediate point of the shell, and traverses the visceral mass to be inserted into the neck by four tongue-like processes. The action of this muscle will be to retract the creature within its shell.

In front of the four branchiæ is situated the penis, upon which lies the œsophagus, and this in turn is surmounted by the brain — these organs filling up the thickness of the neck. The œsophagus (*v*, *v*, *fig.* 114. 5 and 6) is long and slender, and the mouth, according to Cuvier, is a simple anterior opening, in the interior of which a few wrinkles only are perceptible, representing the tongue. The œsophagus dilates into a kind of membranous crop (*w*, *w*, *fig.* 114. 7 and 9), which is succeeded by a muscular gizzard (*x*, *x*, *fig.* 114. 7 and 9) of a cylindrical shape, the walls of which are of tolerable thickness. Both these cavities are furnished internally with longitudinal folds, and these are thicker and more numerous in the crop than in the gizzard (*fig.* 114. 9). The intestine (*y*, *y*,) is slender, and of the same diameter throughout its whole length, which is considerable. It makes two convolutions in the interval between the lobes of the liver (*z* *z*, *fig.* 114. 7). The anus is situ-

ated on the right side of the neck beneath the corresponding lateral fin : the liver is of no great bulk, and forms a nearly globular mass.

The organs of generation consist of an ovary which occupies the greater portion of the right side; of an oviduct of moderate length; of a testicle which is almost as large as the ovary, and of a common deferent canal. The penis is here, as in Clio, an organ altogether distinct from the testicle: it is situated, as already said, beneath the œsophagus, where it is folded upon itself; and when protruded, issues through an orifice placed in the front of the neck and a little below the mouth. It is represented in situ in *fig.* 114. 7, and detached in 8.

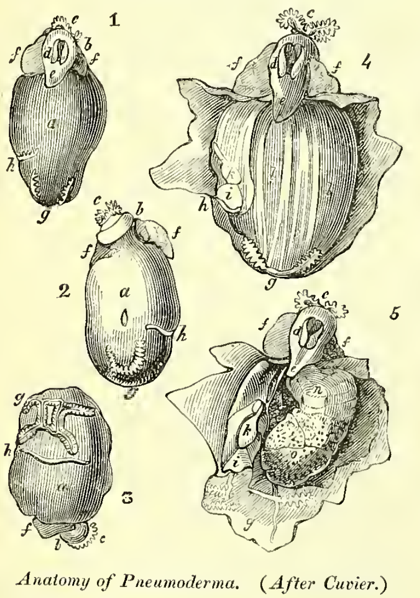
The brain (*fig.* 114. 7, *r*) is large, flat, and of a square form, slightly narrowed posteriorly: the nerves issue principally from its angles, two of them going to join a double ganglion situated beneath the œsophagus.

The salivary glands appear to be wanting.

Pneumoderma. — Another genus of the Pteropod Mollusca, anatomized by Cuvier, embraces the *Pneumoderma*, which presents many peculiarities of structure, more especially as relates to the position of the respiratory organs and the tentacula placed at the sides of the mouth and other anatomical details, so that it will require to be described at length. In this genus, the body is without a shell, having two fins situated on the sides of the neck, but is distinguished by having two bunches of tentacula in the vicinity of the mouth, and by carrying its branchial organs at the surface of its body near its posterior extremity.

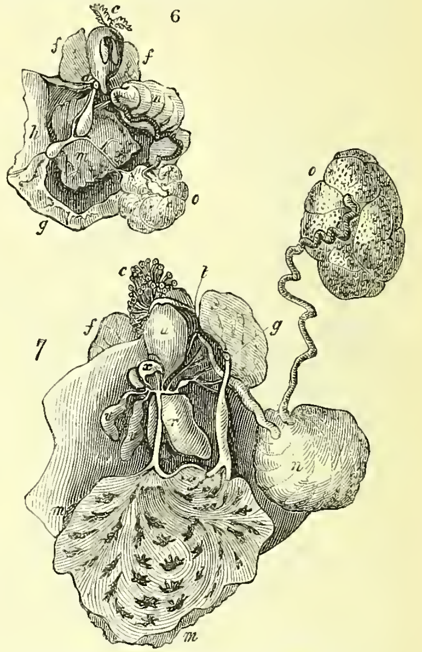
The body of this mollusk is of an oval shape (*fig.* 115. 1, *a*), the head (*b*) is round,

Fig. 115. (1 to 9).

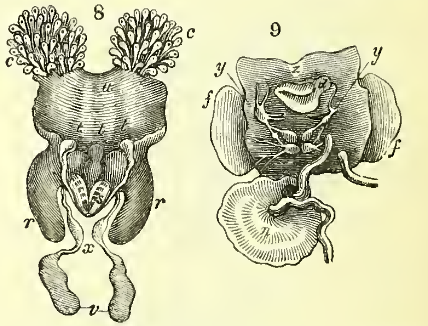


Anatomy of Pneumoderma. (*After Cuvier.*)

1. Pneumoderma, natural size, anterior aspect.
2. The same, posterior aspect.
3. The same placed with the head downwards, and seen from the right side to show the branchiæ.
4. The same enlarged and shown in the position of *fig.* 1. The skin is divided and turned aside to show the muscular envelope of the viscera and the pericardium in situ.
5. The same, the muscular envelope and peritoneum laid open to show the viscera in situ.



6. The same, with the viscera developed.
7. The same: the organs of generation are turned aside; the stomach laid open and the integuments of the head divided to show the mouth and its appurtenances.



8. The mass of the mouth detached and opened longitudinally to show its interior.
9. Interior of the head after the removal of the oral organs, showing the penis and the inferior ganglia in situ.

The same letters answer to all the figures.

a, body; *b*, head; *c*, mouth; *d*, lips; *e*, their fleshy appendage; *f*, fins; *g*, branchiæ; *h*, branchial vein; *i*, auricle of heart; *k*, pericardium; *l l*, muscular envelope of viscera; *m*, liver; *n*, testicle; *o*, ovary; *p*, stomach laid open; *q*, rectum; *r*, *r*, fleshy appendages to oral cavity; *s*, tongue; *t*, *u*, anterior membranous compartment of mouth; *t*, *t*, *t*, oral tubercles; *c*, *c*, tentacles; *v*, salivary glands; *x*, their dilated ducts; *y*, brain; *z*, smaller mucous ganglia; *α*, penis; *β*, opening of common generative canal.

and the neck constricted. The mouth opens upon the summit of the head, and is guarded in front by two longitudinal prominent lips (*d*, *d*), beneath which is a pointed, fleshy appendage (*e*).

The fins (*f*, *f*), attached to the sides of the neck, are fleshy and much smaller than in either of the preceding genera.

The branchiæ (*g*, *g*) are situated at the opposite extremity of the animal, and form two prominent lines somewhat in the shape of two capital Cs placed back to hack and united by a transverse band. These lines give off from each side small prominent laminæ, arranged much in the same way as the leaflets of a pinnate leaf.

On the right side of the body, and a little above the branchial apparatus, is seen a simple prominent line (*h*), which, on opening the animal, is discovered to be the branchial vein opening into the auricle of the heart (*i*), which, enclosed in its pericardium, is situated upon this side (*k*).

On opening the integument, which is comparatively soft, the mass of the viscera is found to be enclosed in a muscular envelope, the fibres of which are almost all longitudinal (*fig.* 115. 4, *l*, *l*). The pericardium is not contained within this fleshy envelope, which is only adherent to the skin in the vicinity of the branchiæ; for in this place are situated the arterial trunks, which convey the blood of the body into the pulmonary organ.

On dividing the muscular layer (*fig.* 115. 5 and 6), it is seen that almost the whole space within is nearly equally shared between the liver (*m*), the testicle (*n*), and the ovary (*o*), the latter being slightly the largest viscus of the three. The ovary occupies the bottom of the visceral sac, the testicle is on the left, and the liver on the right side.

The *stomach* is very capacious, and surrounded on all sides by the liver, which pours the bile directly into its interior through numerous orifices, exactly as in Conchiferous Mollusks. The walls of the stomach are thin and internally present numerous little cavities, into which the biliary pores open (*fig.* 115. 7, *p*). The rectum is short, and opens beneath the right fin (*fig.* 115. 7, *g*).

The mouth is a fleshy mass of considerable size, from which two fleshy appendages are prolonged backwards (*fig.* 115. 7, 8, *r r*). The tongue is covered with short reverted spines, the use of which is evidently to assist in deglutition (*fig.* 115. 8, *s*). The posterior part of the mouth, in which the tongue is situated, is separated from the anterior (*fig.* 115. 7, 8, *u*), which is membranous, by a fleshy construction (*fig.* 115. 8, *ttt*), upon which are perceived three small tubercles.

The opening of the mouth is guarded by two bunches of tentacula (*fig.* 115. 1 to 8, *c*), which the animal can, at will, either protrude or retract within the oral orifice. Each of these tentacles consists of a delicate filament, terminated by a minute tubercle excavated in the centre. These organs forcibly remind us of the complicated oral apparatus of the Clio already described, and most probably are instruments of prehension analogous to those of the Cephalopoda.

The salivary glands (*fig.* 115. 7, 8, *v v*) are long and ample, and their excretory duct, as it passes above the brain, is obviously dilated (*x x*).

The brain (*fig.* 115. 9, *y*) is a narrow transverse band, and among the nerves which it furnishes, two may be observed on each side, which are connected beneath the œsophagus with a group of six ganglia, four of which are mesial and of considerable size, while the other two placed at the sides are of smaller dimensions.

There is nothing peculiar in the structure of the generative apparatus, which nearly resembles that of Hyalea and Clio. The penis is small, and situated beneath the mouth. It is protruded between the two little lips situated upon the anterior surface of the head (*fig.* 115. 1, 5, *d d*). The common generative orifice is found immediately in front of the anus, and is prolonged externally into a kind of furrow, which is directed forwards.

(*T. Rymer Jones.*)

THE PULSE (Gr. σφυγμος, σφυξις, Lat. *Pulsus*, Fr. *Pouls*, Ger. *Puls*, Dut. *Pols*, Ital. *Polso*, Span. *Pulso*).—The nature and cause of the pulse have already been examined in an earlier part of this work.* It is proposed to consider it, in this place, as a separate and independent subject, and to bring together the leading facts which have been ascertained, in reference especially to that property which is most readily submitted to examination, namely, its frequency.

Our knowledge of this subject is little more than a century old; for though Quetelet † attributes to Kepler, who was born towards the end of the 16th century, the idea of ascertaining the number of pulsations in a given time, Floyer, who wrote at the beginning of the 18th century, was the first who collected any considerable number of observations. Bryan Robinson ‡, Falconer §, Knox ‖, Graves ¶, Nick **, and Quetelet †† followed in the same field of inquiry, and still more recently the writer of this article. The facts which these authors placed on record have not yet been brought together in any standard treatise on physiology; so that a clear and connected exposition of the frequency of the pulse, as it is affected by age, sex, posture, exercise, food, and other natural causes, and of the relation which it bears to the respiration, is still a desideratum.

* Art. CIRCULATION, Vol. i. p. 638.

† Sur l'Homme, vol. ii. p. 80.

‡ A treatise on the Animal Economy, by Bryan Robinson, M.D., 1732.

§ Observations respecting the Pulse, &c., by W. Falconer, M.D. F.R.S., Bath, 1796.

‖ Ed. Med. and Surg. Journal, vol. xi., 1815, and No. 131, 1837.

¶ Dublin Hospital Reports, vol. v. 1830.

** Beobachtungen über die Bedingungen, unter denen die Haüfigkeit des Pulses im Gesunden Zustand verändert wird. Von Georg. Heinrich Nick.

†† Op. cit.

It is true that there is no want of rough estimates, or of calculations founded on theoretical data; but there is in this, as in most kindred subjects, a great lack of careful observations, and correct average results. This deficiency it is the object of this article to supply, by presenting in succession the number of the pulse, as influenced by the principal causes already specified.

AGE. — In treating this part of the subject no distinction is made between the sexes, nor is any notice taken of the influence of posture, and time of day. The average results are based on the observations made by different authors on healthy persons of both sexes in a state of rest, and on those of the writer of this article, which, with the exception of very young children, were taken in the sitting posture in the middle of the day, and in a state of rest and abstinence. As these latter facts form the majority of those from which the averages are calculated, it will be correct to state that the tables present a near approximation to the frequency of the pulse in persons of different ages in a state of rest and abstinence, in the sitting posture, and at or about the middle of the day.

The pulse has its maximum frequency in early infancy, and its minimum in robust old age. From infancy to adult age it continues to fall, and probably attains its lowest point at or about the age of 50, to rise again, if feeble as well as robust persons are included in our observations, in the aged.

Infancy. — The frequency of the pulse is very variable at this period of life. According to Quetelet *, the numbers are as follow.

Max. 165; min. 104; mean 135; range 61.

Other authorities estimate it at 130 to 140, or at the last of these numbers; but it will assist the memory to fix the average at 140.

During the first few weeks or months of life, the frequency of the pulse in healthy children is rapidly diminished, as appears from the following Table, based on the observations of Billard, in which table the averages must be understood to be approximations.

Age.	Max.	Min.	Mean.	Range.
1 to 10 days†	180	less than 80	106	100
1 to 2 months	150	70	103	80
2 to 3 months	100	70	87	30

Hence, then, between the first and tenth day there is a range of 100 beats; between the first and second months, of 80 beats; and between the second and third months, of 30 beats, with an average fall in the first three months of about 20 beats. The numbers of observations on which these averages are founded are, between 1 and 10 days, 56 observations; between 1 and 2 months, 36 observations; and between 2 and 3 months, 20 observations.* It would answer no good purpose to enter more minutely into the frequency of the pulse at these early periods of life; it will suffice to present it year by year during the first twenty-five years of life, as is done in the following table, based upon between 600 and 700 observations made chiefly by the writer of this article, each average being deduced either from 20 or 25 facts.

Age.	Max.	Min.	Mean.	Range.
1	158	108	128	50
2	136	84	107	52
3	124	84	106	40
4	124	80	105	44
5	133	80	101	53
6	124	70	95	54
7	128	72	90	56
8	112	72	92	40
9	114	65	87	49
10	120	76	91	44
11	100	56	84	44
12	120	70	94	50
13	112	70	84	42
14	114	68	86	46
15	112	60	84	52
16	104	66	83	38
17	102	54	76	48
18	104	58	74	46
19	108	60	76	48
20	106	52	72	54
21	99	59	74	40
22	96	41	68	55
23	100	60	74	40
24	84	52	71	32
25	88	59	73	29

* Op. cit. vol. ii. p. 86.

† M. Valleix (Mémoires de la Société Médicale de Paris, vol. ii. p. 312.) gives, as the average frequency of the pulse in thirteen healthy infants from 2 to 21 days old, 87 beats, the maximum being 104, and the minimum 76. As these observations were made with singular care, they are entitled to much attention. Mr. Gorham (London Med. Gaz. vol. xxi.) obtained from sixteen observations on sixteen infants, less than one day old, a mean of 123 beats, a maximum of 160, and a minimum of 100; and from forty-two observations on infants, from one to seven days old — 128 as the average, 160 as the maximum, and 96 as the minimum. The average of three experiments on children asleep was 108. M. Trousseau (Journal des Connaissances Médicales et Chirurgicales, Juillet, 1841) obtained, as the average and extreme numbers of the pulse in six boys and five girls, aged from fifteen to thirty days, the following: — boys, max. 152, min. 96, average 127; girls, max. 152, min. 120, mean 135.

* It is necessary to observe, that the observations of Billard, which give so low a frequency as 70 and 80 beats as of not infrequent occurrence before the third month, and even in the first ten days of life, are by no means borne out by the observations of the writer, or of any author whom he has consulted, with the exception of M. Valleix. Thus, the minimum during the first day is 104; nor does the pulse fall in any instance lower than that number till the eighth week, when the least number is 90. If, again, the facts are grouped by months, the pulse is found in no case to fall below 104, except in one instance in the second month, till the eighth month, when the minimum is 96. The minimum observed by M. Valleix, occurred in a male infant, a year old, admitted into the infirmary of the Hôpital des Enfants Trouvés, in a state of languor, but free from disease. In a week from the date of admission the pulse had risen to 108; on the following day it was 117; and the day after that it was 113. There is reason to believe, therefore, that these low frequencies of the pulse of infants occur in that state and degree of debility without disease which gives rise to an infrequent pulse in the adult, and that they do not occur in strong and vigorous health.

This table, though obviously based upon a number of facts too small to furnish exact averages, may be taken as presenting an approximation to the truth. It indicates a progressive decline from infancy to adult age as the true law of the pulse, — a law which would probably be clearly displayed by averages deduced from a large number of facts.

The following table presents the number of the Pulse at each quinquennial period throughout the whole of life. The averages for the first eight periods are founded each on 50 observations, of which half were made on males, and half on females. The average for the period from 76 to 80 is deduced from the same number of facts similarly divided. For most of the other periods the averages are derived from forty observations, twenty on males, and twenty on females. Where the number of observations is less than this, it is stated in a note.

Age.	Max.	Min.	Mean.	Range.
2 to 5	128	80	105	48
5 — 10	124	72	93	52
10 — 15	120	68	88	52
15 — 20	108	56	77	52
20 — 25	124	56	78	68
25 — 30	100	53	74	47
30 — 35	94	58	73	36
35 — 40	100	56	73	44
40 — 45	104	50	75	54
45 — 50	100	49	71	51
50 — 55*	88	55	74	33
55 — 60	108	48	74	60
60 — 65	100	54	72	46
65 — 70	96	52	75	44
70 — 75	104	54	74	50
75 — 80	94	50	72	44
80 and upwards†	98	63	79	35

The want of regularity in this table arises from the same cause as in the former — the comparatively small number of facts. A regular and progressive decrease in the mean values, however, would probably not be obtained by any number of observations which it is in the power of a single individual to bring together, whether as the result of his own inquiries, or as derived from the recorded researches of others. But the figures of this table will still suffice to indicate a law of progressive decrease from the beginning to the end of life, with an increase during the period of decrepitude. The decrease during the first four quinquennial periods is very rapid; during the fourth and fifth the number remains nearly stationary; from the fifth to the sixth period there is again a fall of a few beats; but during the remainder of life (from 25 to 80) a very slight difference exists between the several quinquennial periods; the difference between the averages amounting to only 4 beats, between the minima to 10 beats, and between the maxima to 20 beats. The average rise during the period of decrepitude amounts to 7 beats.‡

* 22 Observations. † 29 Observations.

‡ It would be interesting to accumulate observations on the pulse of the same person at different periods of life. The following memorandum, by the writer, of two series of observations on his own pulse, may be worth preserving. From an average of nine experiments made during my twentieth year, in the evening, between the hours of 9½ and 11½, P.M., in the sitting posture, and, after remaining some time quiet (in one experiment some hours, and in two others during four hours each), the pulse was 72 per minute. From an average of the first nine experiments which present themselves, made under as nearly as possible the same circumstances, in my twenty-seventh year, the pulse is 55 per minute. Thus, in the space of seven years, it may be fairly inferred that the average frequency of my pulse has fallen from 72 beats per minute to 55, being a difference of 17 beats.

The pulse of the aged has been very carefully examined by Leuret and Mitivié*, Hourmann and Deschambre†, and Dr. C. W. Pennock.‡ According to the observations of the first-named authorities, the average frequency of the pulse in 27 males and 34 females, each sex being of the mean age of 71 years, was, in round numbers, 76. The number would have been somewhat higher but for the exclusion, as abnormal, of pulses exceeding 100. Dr. Pennock's observations on 170 males and 203 females, of the mean age of about 67 years, give as the average frequency of the pulse, 75 beats. The observations of Drs. Hourmann and Deschambre having been made solely on females, are not available in this place. It will be seen that the results deduced from the observations of Leuret and Mitivié, and of Dr. Pennock do not differ materially from the numbers in the table.

As it is extremely difficult, even for those who are most in the habit of dealing with figures, to remember the exact results of a series of averages, it may be useful to lay down a near approximation to the average numbers at the several leading periods of life. This is done in the following table.

At birth - - - -	140
Infancy - - - -	120
Childhood - - - -	100
Youth - - - - -	90
Adult age - - - -	75
Old age - - - -	70
Decrepitude - - - -	75—80.

Sex. — The recorded observations on the pulses of males and females respectively during the early periods of life are few in number. At birth, according to the observations of Quetelet, there is a difference of only one beat, the average number in males being 136, and in females 135. The following table contrasts the two sexes at those periods at which the number of recorded observations, added to those made by the writer of this article, are

* De la Fréquence des Pouls, chez les Aliénés, par MM. Leuret et Mitivié, p. 35.

† Archives Générales de Médicine (2nd series), Nov. 1835, tom. ix. p. 338.

‡ Note on the Frequency of the Pulse and Respiration of the Aged. By C. W. Pennock, M. D., American Journal of Medical Science, July 1847.

sufficiently numerous to furnish a fair average.*

	Males.	Females.
Under 2 years - -	110	114
2 — 5 — - -	101	103
5 — 8 — - -	85	93
8 — 12 — - -	79	92

It would appear, then, that even at a very early period of life, the difference of the sexes is marked in the pulse †; that this difference is very inconsiderable in infancy, but well marked in childhood.

The following table presents, in septennial periods, the results of the observations of the writer during the whole of life. Each average is founded on 25 observations, made with great care, in apparently healthy persons, fasting, in a state of rest, in the middle of the day, and in a sitting posture.

Age.	Max.	Min.	Mean.	Range.
MALES.				
2 to 7 years	128	72	97	56
8—14	108	70	84	38
14—21	108	60	76	48
21—28	100	53	73	47
28—35	92	56	70	36
35—42	90	48	68	42
42—49	96	50	70	46
49—56	92	46	67	46
56—63	84	56	68	28
63—70	96	54	70	42
70—77	94	54	67	40
77—84‡	97	50	71	47
FEMALES.				
2— 7	128	70	98	58
8—14	120	70	94	50
14—21	124	56	82	68
21—28	114	54	80	60
28—35	94	62	78	32
35—42	100	56	78	44
42—49	106	64	77	42
49—56	96	64	76	32
56—63	108	60	77	48
63—70	100	52	78	48
70—77	104	54	81	50
77—84§	105	64	82	41

The same remarks apply to this table as to former tables. The number of facts is not large enough to give a steady and progressive decrease from childhood to age; but that the approximation to a true result is sufficiently close for all practical purposes may be inferred from the following comparison of the extreme and mean results derived from 25 and 50 observations respectively on the pulses of healthy males.

No. of Observ-ations.	Age.	Max.	Min.	Mean.	Range.
25	2 to 7	128	72	97	56
50		128	72	97	56
25	7—14	108	70	84	38
50		108	68	85	40
25	14—21	108	60	76	48
50		108	60	78	48

A similar comparison in the female issues in the same manner, as will be seen by the following table.

No. of Observ-ations.	Age.	Max.	Min.	Mean.	Range.
25	7 to 14	120	70	94	50
50		120	70	95	50
25	14—21	124	56	82	68
45		124	56	80	68
25	71—77	104	54	81	50
45		104	54	80	50

It will be seen that in neither comparison does the difference between the averages for the larger and smaller number of observations exceed two beats, while the extremes, with one exception (the minima in the male, from 7 to 14), are the same. The sufficiency of the averages for practical purposes may also be fairly inferred from the result of a simple process of elimination adopted in the case of the female pulse. By taking 26 observations, and excluding the three maxima and the three minima, as being possibly due to a departure from perfect health, an average of 20 observations was obtained, which gave the following regular series of numbers for the twelve septennial periods of the table — 98, 94, 81, 80, 79, 78, 75, 75, 77, 78, 81, 82, showing a steady and progressive decrease during the first eight periods, and an equally progressive increase during the last four periods.

The difference between the male and female pulse continues to be well marked in advanced ages. Thus, in the observations of Leuret and Mitivié, the average frequency in 27 aged men was 73, and in 34 aged women 79. The average obtained by Drs. Hourmann and Deschambre, by observations on 255 aged females, was 82. Dr. Pennock's averages are 72 for aged males, and 78 for aged females.

The general results deducible from the foregoing tables, in reference to the influence of sex on the pulse, may be thus expressed: —

1. The female pulse differs little from the male pulse during the first seven years of life; but after seven years of age the mean pulse of the female exceeds that of the male by from 6 to 14 beats; the average excess being 9 beats,

* The averages are deduced from the following numbers of facts. Under 2 years, 28 and 21 facts; 2 to 5 years, 27 and 23 facts; 5 to 8 years, 32 and 33 facts; 8 to 12 years, 46 and 59 facts.

† This is in accordance with the observations of M. Valleix. (Op. cit.)

‡ An average of 18 observations on males between 80 and 90 by Dr. Pennock gives 72½ beats.

§ Observations by Dr. Pennock on 37 females between 80 and 90 give an average of 75 only; and observations on 7 females between 90 and 115, 76½.

or about one-eighth of the mean frequency in the male.

2. The minimum frequency of the pulse of the female, at more than one period of life, falls below that of the male; but its maximum frequency is, at all periods, above that of the male.

3. The range of the pulse in both sexes is considerable; in the male it extends from 28 to 56, in the female from 32 to 68 beats, and it is probable that more numerous observations would extend this range still farther. The average range in the male is 43; in the female, 48.

4. For the purpose of assisting the memory, the average pulse of the adult male may be stated at 70, that of the adult female at 80. The highest number is somewhat less than 100 in the adult male, and somewhat more than 110 in the adult female. The least number in each is about 50.

The lowest number recorded in the table, as occurring in healthy males, is 46, and in healthy females 52. These, however, are not the least numbers on record; for Heberden counted 42, 30, and even 26 pulses in healthy males, the latter number in a man of 80; and Fordyce one case of 26, in an old man in the Charter-house, and another of 20. The writer, some years since, met with a pulse of 38 in a gentleman then and now in the enjoyment of good, though not robust, health. The lowest number observed by Floyer was 55. Falconer counted a pulse of 36, and another of 24, in healthy females, and Dr. Graves records one of 38. Pulses as low as 16, or even 14 beats, have been counted; but it is doubtful whether the persons in whom they occurred were healthy. Low frequencies of pulse observed in disease are beyond the scope of this essay. On the other hand, it is probable that extended observations would reveal the occasional occurrence in healthy persons of both sexes of higher frequencies of the pulse than any recorded in the tables.

Temperament. — Nothing is at present known of the frequency of the pulse as influenced by temperament. The speculations of Floyer upon this subject are too fanciful, and have too little foundation in fact, to deserve a place among the sober results of observation.* The writer's experience would lead him to attach little importance to temperament as a cause of variation in the pulse, as he has found high and low frequencies in men of the same temperament; and some of the lowest pulses he has observed have been in males of opposite temperaments. It is not uncommon, too, to find pulses of very low frequency in persons of the sanguine temperament, and in men remarkable for energy of character and nervous excitability. The strumous diathesis is often characterised by a feeble pulse of low frequency, while those who are subject to gout have, as a general rule, a stronger pulse of higher frequency. It is probable that, *cæteris paribus*, the large chest and muscular frame are accompanied by an infrequent, and the small chest and spare form by a frequent pulse. But the varying frequencies of the pulse observed in different subjects have yet to be submitted to that extended and searching observation by which alone the several concurrent causes can be successively eliminated, and the most influential circumstances displayed.

Stature. — Bryan Robinson * has some speculations and calculations upon this cause, which deserve to be classed with the fanciful conceits of Floyer. They profess to be strictly founded upon observation; but their fallacy will be apparent, when it is stated that the important element of age is altogether overlooked. Falconer † follows the example of Bryan Robinson; and more recently M. Rameaux ‡, in a letter addressed to M. Quetelet, pursues the same unprofitable inquiry. The observations, 64 in number, were made by M. Pingrenon, an army surgeon. The subjects examined were all healthy soldiers, placed in similar circumstances, which circumstances, however, are not specified, nor are the ages mentioned. The ordinary range of age in soldiers of the same regiment is quite sufficient to account for the very slight differences of frequency which M. Rameaux attributes to stature. How slight that difference is will be seen from the following comparison:—Stature, 5 feet 6½ inches; pulse, from observation, 64·43: stature, 5 feet 9 inches; pulse, also from observation, 62·62. The calculated numbers are 64·06 and 63.§ The effect of stature on the pulse has yet to be determined, and it will require a large assortment of observations made on persons of the same sex and age, at the same time of the day, in the same posture of the body, and placed in all respects under the same circumstances.

Posture. — No part of the subject of the pulse, not even excepting its diurnal variations, has been more carefully examined than the influence of the posture of the body. Though the broad fact, that the pulse in disease is affected by change of posture, seems to have been familiar to the ancients, the first recorded experiment on the healthy subject was made by Bryan Robinson ||, who obtained the following numbers: — Standing, 78; sitting, 68; lying, 64. Dr. Macdonnell is the next person who devoted his attention to this subject, and who appears, from his own statement, to have been engaged upon it so early as the year 1784.¶ Falconer, in his work

* The choleric tempers may be betwixt these numbers 75 and 80, the salt betwixt 80 and 85, the phlegmatic betwixt 70 and 65, the cold melancholy betwixt 65 and 60." — *Pulse Watch*, p. 57.

* Animal Economy, p. 132—134.

† P. 10—13.

‡ Bulletins of the Royal Academy of Brussels, vol. vi.

§ The little importance to be attached to these results will appear, when it is stated that by disregarding the influence of sex, and looking only to the stature of the body, the pulse of the female is made to exceed that of the male by only two or three beats, instead of the true number 9 or 10 beats.

|| Op. cit. p. 177.

¶ Transactions of the British Association for the

published 1796, investigated the subject more carefully, and states, that "the result of twenty-one accurate trials, made on different days and at different times of the day, all coincided to prove the greater frequency of the pulse standing, than sitting or lying." The greatest difference observed was 13 beats in a minute, and the least difference one beat. Each of these, however, occurred once only. The average difference between the above postures was about six and a third in a minute." He adds, "The pulse in health is, as far as I can find, the same in a sitting as in a horizontal posture." Dr. Knox of Edinburgh *, however, has examined the effect of posture on the pulse still more closely than the authors just mentioned. In his first memoir, published in 1815, he says, "During the morning, the mere change of posture, from the horizontal to the erect, shall increase the pulse by about 15 or 20 beats. At midday this increase shall be 10; and in the evening 4, or 6." In his second essay, published in 1837, Dr. Knox gives the results of actual experiment. Nick †, in 1826, and Dr. Graves ‡, in 1830, also examined the subject experimentally. It is unnecessary to pursue the history of this department of the pulse into greater detail, as the fact that the pulse is greatly influenced by posture is now familiar to all medical men. The exact amount of the change due to this cause will, perhaps, be best displayed in the average results obtained by the writer from a large number of facts observed by himself. §

The following averages were derived from observations on 100 healthy males of the mean age of 27 years, in a state of rest, unexcited either by food or exercise, and, for the most part, between the hours of 12 and 2 P.M.: —

Standing, 78·90; sitting, 70·05; lying, 66·62. ||

Difference between standing and sitting, 8·85; between sitting and lying, 3·43; and between standing and lying, 12·28.

These are the average results, from which, however, the extremes are very widely separated; for the difference between standing and sitting ranges from 26 to 0; that between sitting and lying, from 18 to 0; and that between standing and lying, from 44 to 0. The numbers in the observation, at the highest extreme of the scale, were as follows: —

Age, 20. Standing, 98; sitting, 72; lying, 54: differences, 26, 18, and 44.

To the general rule that the pulse is more frequent standing than sitting, sitting than lying, and, *à fortiori*, standing than lying, there are several exceptions. Thus there were 5 instances in which there was no difference between standing and sitting; 19 in which there was no difference between sitting and lying; and 2 in which the pulse had the same frequency standing and lying. Again, the pulse was more frequent sitting than standing in 3 instances; lying than sitting in 11 instances; lying than standing in 5 instances. The total number of instances, in which exceptions to the general rule occurred, was 34, or one-third of the whole.

If we exclude all exceptions to the general rule, and deduce an average from the 66 observations in which the pulse had what may be termed its normal character, we obtain the following numbers: —

Mean age, 27; standing, 81·03; sitting, 71·12; lying, 65·62: differences, 9·91, 5·50, and 15·41.

The female pulse presents some peculiarities worthy of note, as will appear from the following average results of 50 observations made under the same conditions as those just recorded: —

Mean age, 27. Standing, 89·26; sitting, 81·98; lying, 80·24: differences, 7·28, 1·74, and 9·02.

The extreme results, in the female as in the male, are very wide of the averages; for the difference between standing and sitting ranged from 24 to 0; between sitting and lying, from 11 to 0; and between standing and lying, from 28 to 0. The exceptions to the general rule are still more numerous in the female than in the male, the total number of exceptions being 60 per cent., and the number of observations in which exceptions occurred 46 per cent. Of course the rule here referred to is the general rule established by observations on the male pulse.

If, then, we compare the effect of change of posture on the male and female pulse, we discover that the effect is greater, and the exceptions to the rule less numerous, in the male than in the female. This part of the subject will repay a somewhat close examination.

In the following table, the numbers of the pulse, and the differences due to change of posture, are given, in round numbers, the averages being deduced from 66 observations in the male, and 27 in the female, from which all exceptions to the rule are excluded. The mean age in both sexes is 27.

	Standing.	Sitting.	Lying.	Differences.
Males	81	71	66	10 5 15
Females	91	84	80	7 4 11

From this table it appears, that though the female pulse exceeds the male by 10 beats, or $\frac{1}{8}$th, the effect of a change of posture is considerably less in the former than in the latter. But, in order to determine the true relation

Advancement of Science, Dublin Meeting, 1835, p. 97.

* Ed. Med. and Surg. Journal, vol. xi. and No. 131.

† Op. cit. p. 41.

‡ Op. cit. p. 561.

§ Guy's Hospital Reports, Nos. vi. and vii.

|| It is a remarkable coincidence that Dr. Harden, as the average of several experiments on his own person, obtained the same numbers, viz. 80, 70, and 66. See American Journal of Med. Science, vol. v. p. 342.

existing between the pulses of the two sexes in this respect, it is necessary to compare equal things with equal. This is done in the following table, where the pulse in the erect posture, as deduced from 101 observations on males of the average age of 27 years, and 74 observations on females of the average age of 25½ years, is in either sex 86.

	Standing.	Sitting.	Lying.	Differences.
Male	86	77	72	9 5 14
Female		81	80	5 1 6

So that for the same frequency of pulse the effect of change of posture in the male is more than twice as great as in the female. The difference is still more strongly marked in early youth.

The instances in which one or more exceptions to general rules occurred are, as already stated, more numerous in the female than in the male, the exact proportions being 46 per cent. and 34 per cent. The next question connected with the effect of change of posture on the pulse is, whether that effect is the same at all ages? The following table answers this question for both sexes in the negative. The averages are deduced from 30 observations at each age in the male, and 20 in the female.

	Standing.	Sitting.	Lying.	Differences.
MALE.				
Under 20, mean age 15	83	76	73	7 3 10
Above 20, mean age 29		73	69	10 4 14
FEMALE.				
Under 20, mean age 11	92	88	88	4 0 4
Above 20, mean age 38		82	81	10 1 11

Hence, in the male, the difference above 20 between standing and lying is to the difference below 20 as 7 to 5; while, in the female, the difference above 20 is to that below 20 as nearly 3 to 1. The exceptions to the general rule are also more frequent in the young subject.

Another question connected with the effect of posture on the pulse requires to be examined, namely, does that effect vary with the frequency of the pulse? The following tables will be found to furnish an answer in the affirmative. The averages in the first table are founded each on 15, and in the second table on 10, observations.

It will be seen that these tables concur in establishing the general rule, that the effect of change of posture increases with the frequency of the pulse; in the male as the numbers 9, 15, 27, 39; in the female as the numbers 8, 12, 18.

MALES.

	50 to 70			70 to 90		
	Standing.	Sitting.	Lying.	Standing.	Sitting.	Lying.
	61	55	52	81	68	66
Differences.	6	3	9	13	2	15
	90 to 110			110 to 130		
	Standing.	Sitting.	Lying.	Standing.	Sitting.	Lying.
	101	82	74	120	93	81
Differences.	19	8	27	27	12	39

FEMALES.

	60 to 80			80 to 100		
	Standing.	Sitting.	Lying.	Standing.	Sitting.	Lying.
	71	67	63	92	85	80
Differences.	4	4	8	7	5	12
	100 to 120					
	Standing.	Sitting.	Lying.			
	108	97	90			
Differences.	11	7	18			

Another fact bearing on the effect of posture on the pulse, is established by the observations of the writer, in confirmation of less accurate experiments previously made by Dr. Knox and others, viz. that that effect is not the same at all periods of the day. The only satisfactory way of ascertaining this fact is by contrasting the same frequency of the pulse at different periods of the day. This was done by the writer, who employed an average of twenty observations on his own pulse, made before noon, twenty between 12 and 5½ P. M., and twenty between 5½ P. M. and midnight. The greatest average difference between standing and lying (10 beats) occurred before noon, the number in the afternoon being 8, and in the evening 9.

The *cause* of the different frequency of the pulse in different postures of the body is a question of some interest, in examining which

it is necessary to premise that the increase or diminution of frequency attending the change from one posture to another, is not merely a transient effect, dependent upon the muscular effort involved in the act of change, but a permanent state, continuing as long as the respective postures are maintained. This was long since stated by Dr. Graves *, who proved experimentally that when the posture of the body was changed without any effort of its own muscles, "the difference between the frequency in the horizontal and erect postures was not less than when muscular exertion was used." The mode in which Dr. Graves effected this change of posture is not stated; but in experiments performed by the writer of the present article, by means of a revolving board †, a difference amounting to less than a single beat was found to exist between the average of twenty experiments, in which the body was transferred from one posture to the other by the machine, and an average of twenty experiments, in which the change of posture was effected by the voluntary efforts of the same persons. The round numbers with the machine were, — standing 87, lying 74, difference 13; without the machine, — standing 89, lying 77, difference 12. This very slight difference is due to the effort of the muscles in effecting the change of position. When this is subtracted there still remains a much more considerable difference attributable to some permanent cause, which may be either the continuance of muscular effort, or some other condition. The difference of opinion which has existed upon this subject, gives an interest to the following brief summary of the explanations advanced by the leading writers on the pulse.

Bryan Robinson ‡, Falconer §, and Knox, without attempting to submit the question to the test of experiment, attribute, directly or by inference, the different frequency of the pulse, in different postures, to muscular contraction. Dr. Graves ||, however, confesses himself to be altogether at a loss for an explanation; Dr. Arnott ¶ seems to refer it to the more or less favourable position of the body, in respect to gravity, while other authors attribute it to the varying positions of the heart and its valves.** Very little consideration is required to show the futility of all the other causes, except that assumed by Robinson, Falconer, and Knox. The two postures between which there is the most marked difference in the frequency of the pulse, viz. the erect and sitting postures, are precisely those in which there is no difference in the position of the heart or its valves, and very little difference in the resistance offered to the circulation; while the sitting and recumbent postures, between which there is so slight a difference in the number of the pulse, are accompanied by a marked change in the position of the heart and its valves, and of the column of blood to be propelled. On the other hand, the difference in the amount of muscular contraction required to support the body in the erect and sitting postures, is much more considerable than that required to support the body in the sitting and recumbent positions — differences in strict conformity with the observed frequencies of the pulse in the several postures. This simple process of reasoning, therefore, serves to show the fallacy of the explanations now alluded to, and the reasonableness of the remaining alternative — muscular contraction.

With this strong probability the authorities just cited seem to have been satisfied; and as it did not occur to them to submit this very reasonable theory to the test of actual experiment, it was reserved for the writer of this article to place this mooted question beyond the reach of doubt.

The experiments required for this purpose were of the very simplest kind. It was merely necessary in successive experiments to place the body in such circumstances as to exclude every other assigned cause but the contraction of the muscles; in other words, the position of the body, and consequently of the organs of the circulation, remaining the same, first to support the body, and then to call its own muscles into action to maintain its position.

The following are the results of a series of such experiments.

1. Difference between the pulse in the erect posture, without support, and leaning in the same posture, on an average of twelve experiments on the writer, 12 beats; and on an average of eight experiments on other healthy males, 8 beats.

2. Difference in the frequency of the pulse in the recumbent posture, fully supported, and partially supported, 14 beats, on an average of five experiments.

3. Sitting posture (mean of ten experiments on the writer), back supported, 80; unsupported, 87; difference, 7 beats.

4. Sitting posture with the legs raised at right angles to the body (average of twenty experiments on the writer), back unsupported, 86; supported, 68; difference, 18 beats. An average of fifteen experiments of the same kind on other healthy males gave the following numbers: — back unsupported, 80; supported, 68; being a difference of 12 beats.

These experiments, with the simple reasonings already advanced, serve to demonstrate the true cause of the varying frequency of the pulse in different postures of the body to be muscular contraction.

The effect of an inverted position of the body on the frequency of the pulse has been made the subject of experiment by Dr. Graves, and subsequently by the writer of this essay. The reader is referred for an exact account of the experiments to the Guy's Hospital

* Op. cit. p. 562.

† Guy's Hospital Reports, No. VI.

‡ Op. cit. p. 177.

§ Op. cit. p. 34.

|| Op. cit. p. 570.

¶ Elements of Physics, vol. i. p. 570.

** See an Essay by Mr. Blackley, "On the Cause of the Pulse being affected by the Position of the Body," in the Dublin Journal of Medical and Chemical Science, July, 1834.

Reports, No. VII. It will be sufficient to state, that in the inverted position of the body the pulse becomes less frequent, especially in persons accustomed to this unusual posture. In two such instances the difference between the erect and recumbent postures equalled that between the recumbent and the inverted postures, being in both cases 15 beats.

The following is a short summary of the leading facts relating to the effect of posture on the pulse.

1. In the healthy adult male the mean numbers of the pulse are as follows:— Standing, 79; sitting, 70; lying, 67; including all exceptions to the rule. Standing, 81; sitting, 71; lying, 66; excluding all exceptions to the rule.

2. In the healthy adult female the numbers are:— Standing, 89; sitting, 82; lying, 80; including all exceptions to the rule. Standing, 91; sitting, 84; lying, 80; excluding all exceptions to the rule.

3. In both sexes the extremes are very remote from the mean results, and the exceptions to general rules very numerous.

4. In both sexes, also, the effect of change of posture increases as the frequency of the pulse increases; but the exceptions to general rules are more numerous as the pulse is less frequent.

5. The effect of change of posture on any given frequency of the pulse is much greater in the male than in the female.

6. The effect of change of posture on the pulse is less in early youth than in the adult, and the modifying influence of age is greater in the female than in the male.

7. The exceptions to general rules are more numerous in early youth than at the adult age.

8. The exceptions to general rules are more numerous as the effect of change of posture is less.

9. The effect of change of posture on the pulse is greater in the forenoon than in the afterpart of the day.

10. The inverted posture of the body lessens the frequency of the pulse.

11. The varying frequency of the pulse in different postures of the body is due to muscular contraction.

Exercise. — Muscular exertion increases the frequency of the pulse more than any other cause, as will sufficiently appear by the following quotation from Bryan Robinson.* "The pulse, in a minute, of a man lying, sitting, standing, or walking at the rate of two miles in an hour, at the rate of four miles in an hour, or running as fast as he could, were 64, 68, 78, 100, 140, and 150 or more." Change of posture, as has just been proved, forms merely a particular case of muscular effort. The act of changing from one posture to another, and the maintenance of different positions by the action of the muscles, both occasion an increased frequency of the pulse; so also does the stretching out of the arm or the holding of it in the same posture, the pulse rising rapidly with the continuance of the effort, and falling, as the writer has proved experimentally, on returning to a state of rest, below the frequency which it had before the effort was made; and the same observation applies to fatigue induced by long continued exertion, as in walking. The cause of the increased frequency of the pulse which attends muscular effort is partly mechanical, that is to say, depending on the rapid propulsion of the blood through the large veins, and partly due to the effort of the will which sets the muscles in action. It is probable, however, that the first-named cause is by far the most influential.

* Op. cit. p. 177.

Passive exercise, as in riding and the various forms of carriage conveyance, has also a marked effect on the pulse; an effect partly due to the varying action of the muscles in supporting the different postures into which the body is being constantly thrown, and partly to a cause correctly pointed out by Dr. Arnott in the following passage.

"In a long vein below the heart, when the body falls, the blood, by its inertia and the supporting action of the vessels, does not fall so fast, and therefore really rises in the vein; and as there are valves in the veins preventing return, the circulation is thus quickened without any muscular exhaustion on the part of the individual. This helps to explain the effect of the movement of carriages, of vessels at sea, of swings, &c., and the effect on the circulation of passive exercise generally, and leaves it less a mystery why these means are often so useful in certain states of weak health." *

Time of Day — Diurnal Variations of the Pulse. — This subject demands a more minute examination than it has yet received; for it is extremely interesting in a physiological point of view. All the older and several comparatively modern authorities agree in representing the pulse as more frequent in the evening than in the morning. Haller †, Rye and Schwenke ‡, Gregory §, Zimmerman ||, Hufeland ¶, Quetelet **, Fodéré ††, Falconer ‡‡, Double, and Cullen, and, among modern physiologists, Dr. Bostock §§, describe an increase of frequency towards evening; and more than one of these authors speak of a similar change occurring at noon and in the afternoon. Cullen especially insisted on this latter circumstance.

It will facilitate our inquiry if we confine our attention for the present to the frequency of the pulse in the morning and in the evening, or in the earlier and later periods of the day, reserving the alleged increase of frequency

* Elements of Physics, vol. i. p. 52.
† Opera Physiologica, Sectio 2, § xvii.
‡ Quoted by Haller, as above.
§ Conspectus Medicinæ Theoreticæ, cap. xv. ccccliii.
|| On Experience in Physic, vol. i. p. 250.
¶ Makrobiotik, p. 53.
** Essai sur l'Homme Moyen, tom. ii. p. 88.
†† Essai de Physiologie Positive, tom. i. p. 190.
‡‡ Op. cit. p. 24.
§§ Cyclopædia of Practical Medicine, art. Pulse.

at noon and in the afternoon for subsequent consideration.

The earlier authorities who have been cited as favourable to an increase of frequency towards evening were not without support from actual experiments, though those experiments were made in ignorance or disregard of some essential circumstances which tended to impair their value, such as the effect of posture and of food and exercise.

The earliest series of experiments which admits of being employed for the purpose of deciding this question is that contained in the *Medicina Statica Britannica* of Keill, published in 1718, and which the writer has been at some pains to analyse. Next in order of time are the tables of Bryan Robinson, published in his Animal Economy, 1732. The last series of facts, in confirmation of the opinion of the older authorities, was published by Falconer, in his Observations respecting the Pulse, published in 1796. It will economise time and space to present the general results of these three series of experiments in a tabular form.*

	Morning.	Evening.	Difference.
Keill - -	80·50	89·72	9·22
Bryan Robinson			
(Pulses of A.)	70	76	6·00
(Pulses of B.)	68·50	78	9·50
Falconer - -	69·60	76	6·40
Average -	72·15	79·93	7·78

The results of these four series of experiments would appear to furnish a very strong probability in favour of the theory prevailing among the older authorities of an increased frequency of pulse towards the afterpart of the day; and if all the experiments had been made in full cognisance of the influence of posture and other exciting causes on the pulse, and with a due regard to those circumstances, they would have been quite conclusive. Even as it is, they must be admitted to establish a presumption, if not in favour of a universal law, at least for a general rule, or for a frequent exception to the opposite theory. Some experiments, however, performed by Nick† on his own person, of which part were made in the same manner as those of Robinson and Falconer, and part with the precautions just indicated, would lead us to entertain a doubt whether the older authorities may not have been altogether misled by an erroneous or careless mode of performing their experiments. Nick's experiments, performed in the same manner as those of Keill, Robinson, and Falconer, that is to say, without any unusual precautions, gave, as an average of four series, made on four different days, a pulse of 59 at ½ past 7 A. M. and 64 at midnight; and as the result of a single series beginning at 5 A. M. and ending at 10 P. M., a pulse of 59 for the first named hour, and 64 for the last. In each of these experiments the pulse was more frequent in the evening by 5 beats. In both these cases the posture was disregarded; but even when, as in Bryan Robinson's experiments, the sitting posture was preserved in all the observations, but other precautions disregarded, similar results were obtained. Thus, in one instance, the pulse was 66 at 6 A. M., and 71 at 8 P. M.; and in an average of three series of observations the pulse, which was 70 at 9 A. M., was 72 at ½ past 10 P. M. In the one case, therefore, there was an increase towards evening of 5, and in the other of 2 beats. When, however, the experiments were conducted still more carefully, the recumbent posture being preserved in all the experiments, all mental and bodily excitement being avoided, no food taken, and the same temperature preserved, an average of six series of observations gave 63·8 as the pulse at 8 A. M., and 58 at 7 P. M., being a difference of 5·8 beats.

The credit of propounding a diminished frequency of the pulse towards the afterpart of the day, as the true theory, is due to Dr. Knox*, who made several series of experiments, in order to establish it. The general results of these experiments with those of the writer, and some facts gleaned from other sources, are thrown together in a table.†

As the true state of the case did not seem to be made out even by this balance of authority, it was thought desirable to add to the number of observations. Accordingly several averages of the number of the pulse the first

* A minute account of the experiments of Robinson and Falconer, and of the literature of this part of the subject of the Pulse, will be found in the Medical Gazette, June 10. 1839. Keill's observations, from which the averages are calculated, amount to 256 in the morning, and 275 in the evening; the observations of Bryan Robinson were continued for twelve weeks in the first case, and three weeks in the second; while the observations of Falconer were continued almost daily for more than three months.

† Op. cit. p. 5—13.

* Ed. Med and Surg. Journal, vol. xi. p. 53. 1815.

† The second and third experiments of Dr. Knox were made after dinner and supper respectively. For full particulars of his other experiments the reader is referred either to the original essay or to the Medical Gazette, June, 1839. An account of the writer's experiments will be found in the Guy's Hospital Reports, No. viii. Dr. James Saunders' experiments were not made with any view to this question, but as a preliminary to the effect of digitalis on the pulse (Treatise on Pulmonary Consumption). Except when taking large doses of the drug, the pulse retained in this respect its normal character, being, in three experiments (dose 15 drops twice a day), 70 in the morning and 66 in the evening, and in two experiments (dose 25 drops), 76 in the morning and 70 in the evening; but when the dose was raised to 50 drops twice a day, the pulse became 80 in the morning and 90 in the evening, and, on the following day, when the dose was again reduced to 25 drops, it remained at the last named numbers. From some experiments on the pulse, which form part of Dr. Prout's Essay on the quantity of carbonic acid emitted from the lungs during respiration (Annals of Philosophy, vols. ii. and iv. 1813), it would appear that the morning and evening frequency was very nearly the same, the eleven observations in the morning, which correspond with a like number in the evening, giving as averages 70·91 and 70·27.

	Morning.	Night.	Difference.
Dr. Knox - -	68·50	64·38	4·12
" - -	72·00	64·39	7·61
" - -	79·33	63·30	16·03
" - -	79·25	66·66	12·59
" - -	94·60	65·78	28·82
Dr. Nick - -	63·80	58·00	5·80
" - -	——	——	6·50
Dr. Guy - -	64·00	54·00	10·00
Dr. James Saunders	60·00	56·00	4·00
Dr. Harden* -	64·00	62·00	2·00

thing in the morning and the last at night, founded on from two to ten observations at each period, in healthy young persons of both sexes, were obtained, with what result will be seen in the following tables.

STATE OF THE PULSE, MORNING AND EVENING, IN MALES.

Age.	No. of the Pulse.		
	Morning.	Evening.	Difference.
21	67	80	13 in excess
21	71	80	9 ——
20	65	75	10 ——
19	81	71	10 in defect
27	63	61	2 ——
15	92	85	7 ——
18	82	73	9 ——
22	76½	75	1½ ——

STATE OF THE PULSE, MORNING AND EVENING, IN FEMALES.

Age.	No. of the Pulse.		
	Morning.	Evening.	Difference.
22	108	120	12 in excess
51	87	80	7 in defect
26	91	81	10 ——
14	99	81	18 ——
26	92	84	8 ——
24	100	84	16 ——
23	82	82	0 ——
22	101	101	0 ——

The facts contained in these tables and in the previous table, together with the two series of experiments performed by Nick, may be taken to establish the general law first set forth by Dr. Knox, that the pulse is less frequent in the evening than in the morning; but it is obviously subject to numerous exceptions.

This law derives some confirmation from the fact that the only series of experiments on females which the writer has met with (those of Friedrich Hohl on pregnant women†) yield averages in conformity with it; for on comparing the mean of 25 observations made on the pulses of pregnant women in the morning with a mean of the same number made on the same women in the evening, the pulse in the morning was 83·28, and in the evening 80·88, being a difference of 2·40. The same author also states that the pulse of the new-born infant, and of the fœtus in utero are more frequent in the morning than in the evening.* The interval between the morning and evening is filled up by pulses of very variable frequency, where the experiments are not made with due precaution; but where, as in the second series of experiments by Nick, and in those of Knox, and of the present writer, the body remains in the same posture, in a state of rest, and unexcited by stimulating food, the fall in the frequency of the pulse is for the most part progressive, and free from those accelerations at noon and in the evening of which Double and Cullen have made mention.

The diminished frequency of the pulse towards the afterpart of the day seems to depend altogether on the exhaustion of the strength, and is a less degree of that marked diminution of frequency which often accompanies a convalescence from severe disease. That it is not dependent merely on the absence of exertion; in other words, that it is not the effect of continued rest, is proved by the facts now to be mentioned.

It has been experimentally proved, both by Dr. Knox and by the writer of this article, that the pulse is not only less frequent in the evening than in the morning, but that it is also less excitable. So marked is the difference in this respect, that in some experiments recorded in the Guy's Hospital Reports†, the very same food, which in the morning increased the frequency of the pulse from five to twelve beats, and kept it raised above its natural number from one to two hours, produced no effect whatever in the evening. This fact is in strict keeping with the well known effect of spirituous liquors in the early part of the day, as compared with their action on the system in the evening.

The pulse in males appears to follow the same rule in disease as in health. The rule is inverted in females; but in both sexes the exceptions are very numerous.‡

Rest.—From what has already been stated it will be inferred that the absence of exertion has the effect of diminishing the frequency of the pulse.

Sleep.—The pulse falls during sleep, slightly in adults, but considerably in young children. In six observations made by Nick on as many young adults, the mean decrease was somewhat more than three beats. Quetelet, in a girl from three to four years of age, found a

* American Journal of Medical Sciences, vol. v. p. 341.

† Die Geburtshülfliche Exploration, bey Auton Friedrich Hohl.

* An average of twenty-five observations on the morning pulse of the fœtus in utero gave 138·08 beats, and on the evening pulse 135·76, a difference of 2·32 beats. Hohl himself recognizes this fact, and distinctly states that the pulse of the fœtus is more frequent in the morning than in the evening.

† No. viii.

‡ Ed. Med. and Surg. Journal, No. 146.

difference of 10 beats; in a boy from four to five years old, 16 beats; and in a female, in her 27th year, 10 beats. In two pregnant women Hohl observed a difference of 10 and 11 beats respectively; and the same author reports a difference of from 20 to 40 beats in new-born infants. He also attributes a remarkable decrease of frequency sometimes observed in the fœtal pulse to the sleep of the embryo. Other authors have been cognisant of the effect of sleep, but have not made it the subject of experiment.

Food.—The general effect of food is to excite the pulse; this takes place to a very slight extent with vegetable food, but more with animal food. Some articles of diet, as warm drinks, alcoholic liquors, and tobacco have a very marked influence on the pulse. The effect of food is much more considerable in infancy than in after life.*

Mental Emotions.—The effect of these on the pulse is too well known to require any comment.

Temperature of the Body.—Cold lowers the pulse, heat quickens it. Exposure to a very high temperature causes a marked acceleration. Thus Sir C. Blagden, on exposing himself for 8 minutes to a temperature of about 260°, found his pulse rise to 144, or double its ordinary frequency.†

Density of the Air.—In the observations hitherto made, it is very difficult to separate the influence of this agent from that of the exertion which accompanied the change from one medium to another. There was a very considerable increase of frequency in the case of the men who accompanied Saussure in the ascent of Mont Blanc. The pulses that beat at Chamounix 49, 66, and 72, became, on the summit of the mountain, 98, 112, and 100 respectively. Dr. Clark also found the pulses of his companions, in a state of rest on the summit of the mountain, 84, 84, 88, 92, 102, and 108 respectively, being a considerable increase above the probable frequency of the pulses of the same persons under ordinary circumstances.‡ Müller §, on the authority of Parrot, gives a table of the frequencies of the pulse corresponding to different elevations. They are as follows:—Level of the sea, 70; 1000 metres, 75; 1500 metres, 82; 2000 metres, 90; 2500 metres, 95; 3000 metres, 100; 4000 metres, 110. These numbers are probably unauthorised by experiments.

The foregoing are some of the leading causes which affect the frequency of the pulse in health. They may be thrown into two classes; those which increase, and those which diminish its frequency.

1. The more common causes of increased frequency of pulse are:—Exercise, active and passive; continued muscular effort; a change from a posture requiring little, to one requiring more exertion; food, especially warm drinks; spirituous liquors and tobacco; a high temperature; diminished pressure of the air; extreme debility; sleeplessness; the first degree of plethora; and exciting passions and emotions.

2. The common causes of diminished frequency of the pulse are,—continued rest; sleep; fatigue, when not carried to excess; debility, when not extreme, and unaccompanied by disease; cold; increased atmospheric pressure; a change from the erect to the sitting, and from the sitting to the recumbent posture, and the inverted position of the body; and depressing passions of the mind.

Hitherto we have been speaking solely of that character of the pulse which is most easily examined,—its frequency. To render the subject complete, it will be necessary to speak briefly of certain other characteristics of the healthy pulse.

The pulse of the healthy adult male may be described as regular, equal, moderately full, compressible, and swelling slowly under the finger; that of the female, and of the child of both sexes, is smaller, and quicker in the beat. The pulse of persons of the sanguine temperament is full, hard, and quick; that of persons of the lymphatic temperament is softer, and slower in the beat. In old age the pulse, in consequence of the increased firmness of the arteries, assumes a hardness which would not otherwise belong to it.

Exceptions to the general rule are not of very rare occurrence in persons who enjoy good health.—There are some persons, for instance, in whom every slight attack of indigestion, especially when attended with flatulence, leads to a well marked intermission. Instances are also on record in which the pulse is uniformly irregular or even distinctly intermittent in health, becoming regular in disease, and resuming its irregularity on recovery.

One other subject connected with the physiology of the pulse still remains to be examined, viz.

The relation of the Pulse to the Respiration.—The proportion which the pulse bears to the respiration has been variously stated by authors. Quetelet*, Parry†, Burdach, and the greater number of physiologists estimate it as 4 to 1; Joy‡ as $4\frac{1}{2}$ to 1; and Floyer as 5 to 1.§ M. Valleix states it at 4 to 1 in infants. Little dependence, however, is to be placed upon any of these estimates, as they were made in ignorance of the very remarkable effect of posture on the respiration; and as the respiration itself was probably counted for very short intervals of time, and under the disturbing influence of a consciousness of the observation which was being made. Though the posture of the body, in which the pulse and respiration were counted, is not distinctly stated by the authors who have put forward the foregoing estimates,

* Experiments of M. Valleix, Op. cit. p. 336.

† See Sir David Brewster's Natural Magic, p. 311.

‡ See Auldjo's Ascent of Mont Blanc, p. 68.

§ Physiology, vol. i. p. 163.

* Op. cit. vol. ii. p. 86.

† Pathology, vol. i. § 890.

‡ Library of Practical Medicine, vol. iii. p. 274.

§ Pulse Watch, p. 331.

it is most probable that it was the recumbent posture; for it is in that posture that the breathing is most easily counted; and as it is possible, when the subject of the observation is lying down, to place the hand on the abdomen, still retaining the hold upon the wrist, and to count the breathing while he remains unconscious of the object of the observer, the true number of the respirations, as compared with that of the pulse, may be ascertained with tolerable accuracy. Eighteen such observations, made by the writer on as many healthy young men, gave as the average proportion 3·72 to 1, and thirteen observations on as many more healthy and adult females, the proportion of 3·61 to 1. The extremes, in the observations on males, were 2·54 to 1, and 5·33 to 1; and in females, 3·10 to 1, and 4·33 to 1. In these observations the respiration was counted, immediately after the pulse, for two consecutive minutes. Bryan Robinson, as the result of three observations on the same number of healthy males in the sitting posture, obtained numbers of the pulse and respiration, from which the calculated proportions are 3·82 to 1, 3·79 to 1, and 3·86 to 1. Quetelet*, from a series of 300 experiments on males of different ages, obtained the following proportions: —

At birth,	3·09 to 1.
5 years of age,	3·38 to 1.
15 to 20 - -	3·72 to 1.
25 to 30 - -	4·43 to 1.
30 to 50 - -	3·88 to 1.

In his own case, the average proportion was 4·19 to 1. From a smaller number of observations on females, the following proportions were obtained: —

At birth,	3·09 to 1.
15 to 20 years of age,	4·10 to 1.
20 to 25 - -	4·52 to 1.
30 to 50 - -	3·92 to 1.

From other observations by the same author, it would appear that the proportion of the pulse to the respiration during sleep is lower than in the same persons awake, in consequence of the respiration being more affected during sleep than the pulse. Thus, in a girl from 3 to 4 years of age, the mean proportion of the pulse to the respiration was 3·40 to 1 awake, and 3·68 to 1 asleep; in a boy from 4 to 5 years old, 3·21 to 1 awake, and 3·50 to 1 asleep; and in a female in her 27th year, 2·85 to 1 awake, and 3·19 to 1 asleep. The averages are deduced from "*un assez grand nombre d'observations*," and were probably made in the recumbent posture.

Drs. Hourmann and Deschambre obtained, as the result of 255 observations on aged females, 3·41 to 1, or, excluding extreme frequencies both in excess and defect, 3·65 to 1. Dr. Pennock, from 146 observations on aged males, obtained a mean of 3·51 to 1, and from 143 observations on aged females, 3·53 to 1.

* Vol. ii. p. 86.

As the respiration is greatly under the control of the will, to obtain the requisite accuracy in observations of this nature it would be necessary to adopt some measures by which it might be counted for several minutes at least in succession, the subject of the observation being either unconscious of what is going on, or having his attention diverted from it. This object the writer has accomplished by converting the common pocket pedometer into an instrument for registering the respirations; and by means of it, has made several hundreds of observations during periods of half an hour each, the pulse being counted for one or two minutes before and after each registration of the respirations, and the average of the two or four minutes being taken to represent the frequency of the pulse during the whole period of the experiment. The greater number of the experiments were made in the sitting posture, with the back supported, the attention being diverted from the breathing by engaging in study.* The, following are the principal results obtained in this manner: — the average proportion from 238 experiments performed in the manner just described, the pulse varying from 44 to 85 beats, and the respiration from $15\frac{1}{2}$ to $20\frac{1}{2}$, was 3·47 to 1. The extreme proportions were 2·61 to 1, and 5 to 1.

The average proportions varied with the number of the pulse; as shown in the following table: —

No. of Observations.	Pulse.	Proportion.
8	45—50	2·75 to 1
37	50—55	3·05 to 1
50	55—60	3·31 to 1
50	60—65	3·52 to 1
50	65—70	3·59 to 1
27	70—75	3·82 to 1
12	75—80	4·18 to 1
4	80—85	4·31 to 1

From the results of these experiments, then, it would appear that the proportion which the pulse bears to the respiration, in the same posture of the body, diminishes as the frequency of the pulse increases.

Another fact established by these experiments is the different frequency of the respiration morning and evening for the same frequency of pulse. Thus, for a pulse of 63, being an average of 50 experiments in the morning and 50 in the evening, the number of respirations in the morning was 17·60, and in the evening 18·58, being as nearly as possible as the numbers 17 and 18.

The effect of posture on the respiration, and the proportion which it bears to the pulse, is, however, still more remarkable than that of the time of the day. Thus, to take the only instance in which it was possible to compare the proportion of the pulse to the

* An abstract of the results of these experiments was first published in the first part of Hooper's Physician's Vade Mecum, edited by the writer early in the year 1842.

respiration in three postures of the body for the same number of the pulse: the pulse being 64, the proportions were: —

standing, 2·95 to 1.
sitting, 3·35 to 1.
lying, 4·97 to 1.

Again, an average of 14 experiments, in which the pulse in the sitting and recumbent posture had the same frequency, namely, 62·40, gave the following results:

sitting, 3·30 to 1.
lying, 4·39 to 1.

The difference between the erect and sitting posture is less considerable, as will appear from the following average results of six observations, in which the pulse had the same frequency in these two postures, namely, 61·45:

standing, 3·05 to 1.
sitting, 3·40 to 1.

The proportion which the pulse bears to the respiration, therefore, is greater in the erect than in the sitting posture, and in the sitting than in the recumbent posture; but the difference is greater in the latter than in the former case.

If experiments made with great care upon a single individual in the enjoyment of good health may be employed to establish general rules, the following may be laid down in reference to the proportion between the pulse and respiration.

1. The proportion which the pulse bears to the respiration varies greatly with the frequency of the pulse.

2. The proportion of the pulse to the respiration decreases as the frequency of the pulse increases.

3. The proportion of the pulse to the respiration for the same frequency of the pulse is greater in the evening than in the morning; the respirations in the evening being to those in the morning as 18 to 17.

4. The proportion of the pulse to the respiration varies in different postures, being higher in the erect than in the sitting, and in the sitting than in the recumbent posture; the difference between the sitting and the recumbent posture being greater than between the sitting and erect posture.

Since these results were published, Dr. Harden, of Georgia, U. S., has published an account of some experiments on the pulse and respiration* made on his own person, but without the use of any registering instrument. They are, to a certain extent, confirmatory of the results obtained by the writer. The average number of respirations was as follows: — Standing, 16; sitting, 14; lying, 12; the average numbers of the pulse in the same postures, 80, 70, and 66. By selecting from the table published by Dr. Harden five observations, in which the pulse, in each of the three postures, was 68, the following numbers are obtained: — Respirations, standing, 15·2; sitting, 14·4; lying, 13. The proportions consequently are 4·47 to 1, 4·72 to 1, and 5·23 to 1, which follow the same order as the experiments of the writer, though they present smaller differences. The respirations are also more numerous in the evening than in the morning, in the proportion of 13½ and 13, the pulse being 62 at the former period, and 64 at the latter.

* Observations on the Pulse and Respiration, by John M. B. Harden, M.D., of Liberty County, Georgia. American Journal of the Medical Sciences, April 1843, vol. v. p. 340.

Calculations founded on the observations of Dr. Pennock, already more than once referred to, confirm the preceding results, as far as the standing and sitting postures are concerned.

As the calculations in question serve to exhibit the relation existing between the Pulse and Respiration in advanced age, as well as, by inference, the increasing frequency of the respiration in the aged, they are appended in a tabular form.

Age.	Sitting.	Standing.
Males.		
50—60	3·71 to 1	3·68 to 1
60—70	3·39 to 1	3·26 to 1
70—80	3·29 to 1	3·23 to 1
80—90	3·07 to 1	2·96 to 1
Females.		
50—60	3·65 to 1	3·61 to 1
60—70	3·62 to 1	3·62 to 1
70—80	3·69 to 1	3·49 to 1
80—90	3·46 to 1	3·29 to 1
90—115	2·94 to 1	2·66 to 1

These results are somewhat at variance with those obtained by Hourmann and Dechambre, who found both the pulse and respiration to increase in frequency with the advance of age, but in consequence of the former increasing more rapidly than the latter, the proportion between the one and the other diminished instead of increasing. The effect of posture on the pulse and respiration was not examined by them; and it is probable that their observations were made in the recumbent position.

Such are the leading results of careful observation on the frequency of the pulse as affected by the more influential natural causes.

Bibliography. The leading monographs and essays which contain well observed facts bearing on the physiology of the pulse, will be found among the references in the foot-notes. The older works are so filled with fanciful conceits, and are so little likely to be referred to, that it has not been thought necessary to give a list of them in this place.

(*William A. Guy.*)

QUADRUMANA. — The four-handed order of Mammalia, deriving their name from the thumb being opposed to the other fingers and toes, in the feet as well as in the hands, by which peculiarity they are enabled to grasp objects both with their anterior and with their posterior extremities. According

to zoological and zootomical observations, they ought to be divided into two great families, the *Simiæ* and the *Lemurinæ*.

I. Simiæ. *Monkeys. Singes*, French. *Affen*, Germ. *Apen*, Dutch.

This name includes the *Quadrumana* with four vertical incisor teeth in each jaw, and in general flat and similar nails at the tops of the fingers and toes, two characters by which they approach to man; the molar teeth have smooth tubercles, and consequently they feed in general upon fruit; but the canine teeth are stronger than in man, and have their summits not in the same level as the other teeth, but more prominent. There is consequently, in the same manner as in the Carnivora, an interval in the upper jaw, between the exterior incisor and the canine tooth, in which the canine of the opposed jaw is received. They consist of two distinct groups, of which the first is confined to the old world, and is familiarly known under the name of *Apes, Monkeys*, and *Baboons*. These, the anatomical structure of which will be described in the first instance, have the same number of teeth as man, and approach to him in many respects, but differ so much from each other, that it is necessary to divide them into various genera.

1. Simiæ veræ, Monkeys of the Old Continent, *Simiæ catarrhinæ* Geoffr. In general the same number of teeth as in man, viz. incisors $\frac{4}{4}$; canines $\frac{1-1}{1-1}$; molars $\frac{5-5}{5-5}$. Nostrils situated under the nose.

a. *First Genus. Simia. Ape.*

In general the same number of teeth as in man, but stronger, especially the canine; an interval between the exterior incisor and the canine in the upper jaw. No callosities on the buttocks; no tail; the fore-feet or arms much longer than the hinder. The hair of the head is directed forwards, so as to shade the temples, and that of the fore-arm reverted upwards, in the direction of the elbow, where, encountering the hair of the humerus, which grows in the opposite direction, it stands out in the form of a prominent ruff. They want the cheek-pouches, but possess very large membranaceous expansions communicating with the larynx. In the form of the hyoid bone, in the structure of the brain, and many other parts of their organisation, they approach the nearest to man. They inhabit tropical Asia and equinoctial Africa.

Spec. — *Simia troglodytes*, Chimpanzee; *Simia Satyrus*, Orang-œtan.

b. *Second Genus. Hylobates* Illiger. *Gibbon*, French. *Armaffe*, Germ. *Langarmige Aap*, Dutch.

The same excessive length of the arms, which are so long as to touch the ground, when the animal is in a semi-erect attitude. Callosities on the buttocks, as in the *Cercopitheci*, from which the *Gibbons* differ by the want of a tail, and of cheek-pouches. The form and number of teeth are the same as in *Simia* and in *man*, but the crowns of the true molars have a more rounded contour than in the inferior quadrumana, and in their relative size they resemble more the molars of the *Carnivora* than do those of the genus *Simia*. The *Gibbons* are restricted to the forests of tropical India, and their activity in climbing is surprising. They want the laryngeal pouch.

Spec. — *Hylobates lar*, *H. variegatus*, *H. leuciscus*, the *Siamang* (*H. syndactylus*) ought to be separated from the other *Gibbons*. It has the second and third toe* united by a narrow membrane, extended over the whole length of the first phalanx, and possesses a laryngeal pouch. Its skeleton approaches most to that of man. Its hair is directed as in the *Orangs*.

c. *Third Genus. Semnopithecus* F. Cuv. *Slank-aap*, Dutch.

Long, but slender and *straight* tail.† They have no cheek-pouches, but they possess a membranaceous, and small laryngeal, expansion. Callosities on the buttocks. Extremities, principally the hinder, very long, as also the fingers and toes, with the exception of the thumb of the hinder hand or foot, which is short, and removed from the outer toes. The slenderness of their body, and largely-developed extremities, enable the *Semnopitheci* to display a great deal of activity. Their stomach is very large, and divided into three or four pouches. The teeth differ from those of the *Gibbons* by the existence of a posterior tubercle on the last molar teeth of the lower jaw. They inhabit the Indian Continent and the Indian islands, principally Borneo, and are there the constant companions of the *Gibbons*, with which they have a great analogy.

Spec. — *Semnopithecus entellus*, *S. leucoprymnus* (including *Simia latibarbata*, *Cephaloptera*, and *S. Nestor*, Benn.), *S. leucomystax*, *S. mitratus*, *S. melalophos*, *S. rubicundus*, *S. chrysomelas*, *S. maurus*, *S. frontatus*, *S. nemæus*, *S. nasicus*. To these could be added, 1. *S. cucullatus*, but it seems but a local variety of *S. leucoprymnus*; 2. *S. Siamensis*, which is a local variety of *S. mitratus*; 3. *S. flavimanus*, which is a local variety of *S. melalophos*; 4. *S. Sumatranus*, local variety of *S. chrysomelas*; 5. *S. cristatus*, variety of *S. maurus*. S. Muller and H. Schlegel presume that *S. albogularis* Sykes is a variety of *S. entellus*; but according to the observations of Ogilby, this monkey is a *Cercopithecus*. In the enumeration of the

* According to the observations of Ogilby and F. Cuvier, this character is not exclusive in the *Siamang*, but obvious also in many other species of *Gibbons*.

† S. Muller and H. Schlegel have proved in their monograph on the genus *Semnopithecus*, that it is by a mistake that most of the authors on natural history describe and figure the tail of *Semno-pitheci* as incurvated in the same manner as in squirrels. It hangs straight below when they climb, and is merely horizontal and touching the ground when they walk.

other species, I followed the direction given by the said authors.

d. *Fourth Genus. Colobus* Illiger.

This genus represents in North Africa the *Semnopitheci* of South Asia, and seems only to differ from them by the rudimentary condition of the thumb, and, in one species, *C. verus* Van Beneden *, by the total want of it. By this disposition the *Semnopitheci* and *Colobi* may be compared with the genus *Ateles* from the New World, in which some species want the thumb, and others possess it: they seem, in fact, to represent that genus in the Old World, having a great deal of conformity with it in structure, manners, and character. Ruppell † has proved, by dissection of the *Colobus guereza*, that in this genus the stomach approaches to that of the *Semnopitheci*, by its extension and the existence of separate cells. The teeth are the same as in the *Semnopitheci*, viz., with an additional tubercle to the posterior molar of the lower jaw. The first molar of the lower jaw on each side is inclined backwards, and gives also room for the canine of the upper jaw. In both the *Semnopitheci* and *Colobi*, detrition of the molar teeth seems to take place in a longitudinal direction, as has been shown by Ogilby, indicating a corresponding motion of the jaws, something similar to what takes place in the *Rodentia*. They have cheek-pouches and ischial callosities.

Spec. — *Colobus polycomos, C. ferrugineus, C. guereza, C. verus.*

e. *Fifth Genus. Cercopithecus. Monkey,* Engl. *Guenon,* Fr.

Prominent jaws; cheek-pouches; naked callosities on the buttocks, and long but not slender tail; arms much shorter than the posterior limbs, by which disposition the *Cercopitheci* climb with much agility, but walk with more difficulty: consequently they are sylvan in their habits, and confined in general to the woods of Africa. They possess in general a laryngeal pouch, and their posterior molar of the lower jaw wants in general the additional tubercle proper to the *Semnopitheci*. The first molar of the lower jaw is disposed as in *Colobus*. They are quick, capricious, choleric, cunning, and very teachable. They are a pre-eminently sylvan race, and live in the forests in society, under the guidance of the old males. Each tribe or family has its own particular district, into which individuals of other tribes or species are not allowed to intrude. So strongly is this propensity implanted in the *Cercopitheci*, that they carry it with them even into our menageries. They feed indiscriminately upon wild fruits, the seeds and buds of trees, insects, birds' eggs, &c., but appear on the whole to be less carnivorous in their appetites than either the *Apes* or *Cynocephali*.

Spec. — *Cercopithecus ruber, C. Æthiops, C. fuliginosus, C. Sabæus, C. griseo-viridis, C. melarhinus, C. faunus, C. pygerythrus.* To this genus are also referred the *C. mona, C. cephus, C. petauristus, C. nictitans,* and *C. Diana*, which, according to the observations of F. Cuvier, form a separate group, distinguished by their elegance of form and gentleness of manners and character. All these and the preceding *Cercopitheci* inhabit chiefly Africa. I intend also to introduce, upon the authority of Ogilby and Schlegel, in this genus three Asiatic and chiefly Indian species, which are referred by others to the genus *Macacus*, viz., *C. cynomolgus, C. radiatus*, and *C. pileatus*, Ogilby. They have an additional tubercle on the posterior molar of the lower jaw, and differ by it from the other species of the genus *Cercopithecus;* but in their general form, external aspect, and manners, they offer the greatest analogy with the *Cercopitheci*, constituting a natural group with them, and forming, at the same time, a transition to the genus *Inuus*. I am fully convinced, that in forming a natural system, it is very wrong to be led by a *single* anatomical character. This additional tubercle of the molars is unquestionably a subordinate character, insufficient of itself to induce us to separate animals belonging to the same natural group. Geoffroy St. Hilaire seems to have had the same views, by the formation of his genus *Cercocebus*, in which he places the above-named three species, and Ogilby says that he found in the *Mangabey* and in the *Collared Mangabey*, which every one refers to the genus *Cercopithecus*, the tubercle in question; a proof that it is not an essential character. Recently I. Geoffroy St. Hilaire has separated the *C. melarhinus* or *Talapoin* from the other *Cercopitheci*, and has formed of it a new genus *Miopithecus*. The principal character is the existence of only three tubercles on the posterior molar of the lower jaw. But I am of opinion, that this is not sufficient for the formation of a separate genus. If such merely anatomical characters are admitted for the classification of animals, there will be within a short time as many genera as there are animals.

f. *Sixth Genus. Inuus* Schlegel. *Macacus* Cuv. *Macaque*, Fr. *Laponder-aap*, Dutch.

Upon the authority of my distinguished friend Schlegel *, curator of the splendid museum at Leyden, I am induced to unite the genus *Macacus* Cuv. with the genus *Inuus* Schlegel. They form together a natural group, in which the tail becomes gradually shorter, and finally disappears, in the *Inuus sylvanus* or *ecaudatus*. An elongated muzzle, much more prominent than in the *Cercopitheci*, with nostrils opening

* P. S. Van Beneden, Notice sur une Nouvelle Espèce de Singe d'Afrique, tom. v. n. 6. Bull. de l'Acad. Royale de Bruxelles.

† E. Ruppell, Neue Wirbelthiere zu der Fauna von Abyssinien. Frankf. a. M. 1835—1840.

* Ogilby seems to agree with these views, by the formation of his genus *Papio*, which is much similar to my genus *Inuus*.

obliquely in its upper part, and a protruded superciliary ridge, give a peculiarly cunning, mistrustful, and somewhat ferocious physiognomy to these *Inui*, especially to the old ones. Their limbs are strong and compact; by them, and by the shortness or the want of a tail, they are more a terrestrial than an arborial genus. They devour frogs, lizards, and large insects, as readily as vegetable substances. They possess naked callosities, cheek-pouches, and laryngeal expansions. Their canines are very strong, and the posterior molars of the lower jaw have an additional tubercle. By the great development of the superior canine, the first molars of the lower jaw are inclined backwards on each side, and thus make room for the reception of those teeth. This character appears first in *Colobus* and *Cercopithecus*, but it is not so distinct in these as in *Inuus*. Among the *Cercopitheci* it is the most apparent in *C. cynomolgus*, by which, and by the existence of the additional tubercle on the posterior molars of the lower jaw, this forms, with its two congeners *C. radiatus* and *C. sinicus* or *pileatus*, a transition to *Inuus*. This inclined direction of the first molar of the lower jaw becomes more distinct by age. It is rendered necessary, by the length of the superior canine tooth, and by the uninterrupted series of the canine and first molar in the lower jaw. By the action of the superior canine, there is produced a surface for trituration, in the external surface of the anterior root of the first molar.

The *Inui* inhabit generally eastern India. They are very gentle, industrious, and intelligent in their youth, but become ferocious and untameable in their old age.

Spec. — *Inuus rhesus*, *I. speciosus*, *I. nemestrinus*, *I. maurus*, *I. sylvanus* or *ecaudatus*. Amongst these the *I. sylvanus* is not only remarkable by the want of a tail, but also by being the only one of this genus which comes within the geographic range of Europe; great numbers, originally from Barbary, still inhabiting the inaccessible precipices of the rock of Gibraltar.

g. *Seventh Genus*. *Cynocephalus* Cuv. *Baboon*, Engl. *Papion*, Fr. *Baviaan*, Dutch.

The same teeth as *Inuus*, but the canini of the upper jaw are enormously developed, and consequently the first molars of the lower jaw are still more inclined. The cheek-pouches, the callosities, and the laryngeal expansions, as in the precedent genera. The tail is either short, thick, and ending in a tuft of hair, or altogether deficient. A large, dog-shaped head, with a prominent, truncated, or, as it were, abruptly cut-off muzzle, with the nostrils opening at the end, gives a hideous aspect to the *Cynocephali*, corresponding to their ferocious, disgusting, and formidable manners. To the prolongation of the face, and preponderance of the anterior over the posterior part of the head, is to be attributed, at least in a great measure, the fact that the *Cynocephali* less frequently assume the erect posture than any of the other Quadrumana, and even when they do, are less capable of maintaining it for any length of time. They are essentially constructed for terrestrial progression. Their whole habits, as well as their organic structure, approximate these animals to the ordinary quadrupeds. The great development of their organs of smell; the position of the nostrils; the robust make of their extremities, and their equality in point of length; the size and power of their canine teeth, and the nature of their food; all indicate their inferiority to the *Apes* and *Monkeys*. Their natural food consists of wild berries and bulbous roots, bird's eggs, insects, &c. In search of food, they go in large companies upon marauding parties, reciprocally to support each other, and to carry off their plunder in greater security. They inhabit principally Africa and the Philippine islands.

Spec. — *Cynocephalus silenus*, *C. Sphynx*, *C. porcarius*, *C. hamadryas*, *C. gelada*, *C. niger*, *C. leucophæus*, *C. mormon.**

I refer the *C. silenus* or *Ouanderou* to the *Cynocephali*, by the prevailing authority of Dr. Schlegel. The general physiognomy of this monkey, and the brush at the extremity of the tail, are sufficient characters to justify this determination. The *C. silenus* forms with the *C. niger* the link of a chain uniting our genus *Inuus* with *Cynocephalus*. In both, the nostrils are not terminal, nor is the muzzle truncated, but disposed as in the *Inui*, while by the other characters they are *Cynocephali*. The *Gelada*, which was first brought to public notice by the celebrated Dr. Ruppell, is certainly a *Cynocephalus* nearly allied to *C. hamadryas*. In a skull of this monkey in the museum at Leyden, I was struck with the great conformity it has with the skull of the larger *Cynocephali*, for example, with the skull of *C. porcarius*. It has the same prominent superciliary ridges, the same deep orbits, the same prominent maxillary bones, and, above all, the same deep fossa on the facial surface of the supra- and infra-maxillary bones. The *Drill* (*C. leucophæus*) and *Mandrill* (*C. mormon*) ought to be separated from the rest by a typical pre-eminence. Their cheeks are prominent, deeply ridged, and in the *Mandrill* beautifully coloured.

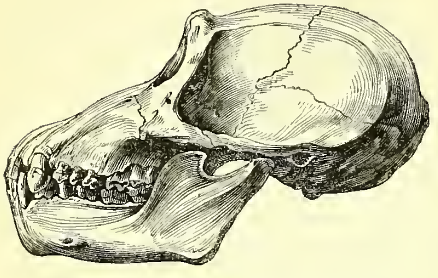
Osteology. — If we consider the bony framework of all the monkeys of the Old World, we find in it no less numerous differences than in their external form and habits. We may trace in it some successive stages, by which they deviate from the structure of man, and approximate to the skeleton of the larger *Carnivora*. As I have stated elsewhere, they form an uninterrupted series, in the descending scale, beginning with the *Chimpanzee*, and ending with the *Cynocephali*.

The skull of the *Chimpanzee* (*fig.* 116) is of a narrow, elongated form, slightly contracted

* Recently I. Geoffroy St. Hilaire has separated the *C. gelada* under the name of *Theropithecus*, and the *C. niger* under the name of *Cynopithecus niger*. But I am afraid that the introduction of all these new genera does not constitute an improvement for science.

towards the anterior part, which is, as it were, truncated. The cerebral portion, or the cra-

Fig. 116.



Skull of Simia troglodytes. (*After Owen.*)

nium, is smooth, and convex on its superior or coronal aspect, being devoid of the intermuscular frontal and sagittal crests, which give so strong a carnivorous character to the skull of the *Orang-œtan*. For the insertion of the temporal muscle there is, however, a long boundary continued from the outer part of the supra-orbital ridge, at first as a well-marked crest, but soon becoming a slightly elevated line, which is lost in the lambdoidal and supra-auditory ridges. The coronal suture has a transverse direction; the occipital foramen is further from the posterior plane of the cranium, and its position is less oblique than in the *Orang-œtan*. Consequently there is a greater proportion of brain behind the *meatus auditorius externus* in the *Chimpanzee* than in the *Orang-œtan*. Behind the condyle of the lower jaw there is, in the glenoid cavity of the temporal bone, a process, of which the rudiment exists also in man, affording a support for the jaw to guard against a backward dislocation. The frontal bone is single as in man, but distinguished by large projecting supra-orbital ridges, which form a sort of line of demarcation between the cranium and the face. The squamous portion of the occipital bone is of considerable extent, more convex than in the *Orang*, and consequently more like that of the human subject. The squamous portions of the temporal bone extend over a smaller portion of the sides of the cranium than in *man*, and their superior margin, instead of forming a convex curve, is almost a straight line. The mastoid processes are represented on either side by a mere ridge of bone, and the styloid processes by small tubercles. The condyloid processes of the occipital bone are proportionally smaller than in the human subject. The *foramen magnum* is situated in the middle of the posterior third of the *basis cranii*, and its plane is inclined upwards from the anterior margin at an angle of 5° from the plane of the basilar process; there are no posterior condyloid foramina but the anterior condyloid foramina, the *foramina jugularia*, *stylo-mastoidea*, *carotica*, *spinosa*, and *ovalia*, are in nearly the same relative position as in *man;* the principal difference is in the greater distance between the *foramen caroticum* and the *foramen ovale*, in consequence of the greater antero-posterior extent of the petrous bone.

In consequence of the proximity of the *foramen magnum* to the posterior margin of the skull, a considerable extent intervenes between it and the posterior margin of the bony palate; this is occupied by the large development of the petrous bones, and a corresponding extent of the basilar element of the occipital. The antero-posterior diameter of the bony palate, in like manner, greatly exceeds that of the corresponding part of the human skull. The zygomatic arches are opposite the middle third of the skull, as seen from below, while in the human cranium they are included in the anterior moiety.

The form of the *basis cranii* differs generally from the *bimanous*, and manifests the *quadrumanous* type, in its greater length, in its flatness, in the small extent of the receptacle for the brain behind the *foramen magnum*, in its contraction between the *zygomata*, and in the large size, and especially the anterior development, of the bony palate.

A character, by which the *Chimpanzee* approximates more closely than the *Orang* to the human subject, is presented by the nasal bone, which projects, in a slightly arched form, beyond the interorbital plane, while a trace of its original separation into two lateral elements remains at the lower margin of the consolidated and single bone.

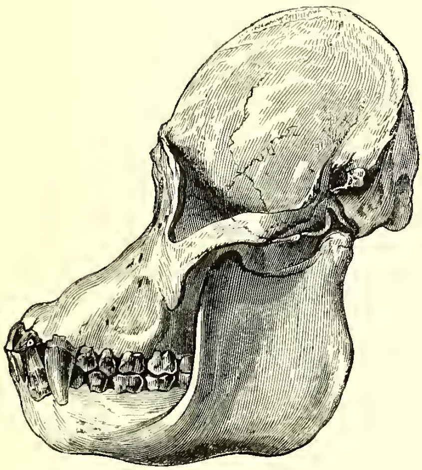
The ascending or nasal portion of the superior maxillary bone, which is of greater proportionate size than in the human subject, does not ascend vertically to the orbits, as in man and some of the lower *Quadrumana*, but slopes backwards, as in the *Cynocephali* and in the carnivorous mammalia, but in a less degree. The contour of the upper jaw, from the nasal aperture to the incisor teeth, is almost straight, while in the *Orang* it is rendered concave by the greater development of the intermaxillary bones in the anterior direction. These bones are anchylosed to the maxillary bones in the adults of both the *Chimpanzee* and *Orang;* but in the *Chimpanzee* the anchylosis takes place at a much earlier period. In the same manner as in man the original separation remains visible, in the palate external to the *foramina incisiva*. The lower jaw, like the upper, is equally characterised by its strength and size in relation to the entire skull; the symphysis or chin recedes; but the depth of the jaw in front is less than in the *Orang-œtan*. The ramus of the jaw forms a more open angle with the body than in the *Orang-œtan*, and thus more nearly resembles the human structure. The dental formula of the *Chimpanzee* is as I stated before. The teeth approximate in their proportionate size much more nearly than those of the *Orang-œtan* to the human teeth, but they differ by the absence of unbroken proximity. A well-marked interval separates the upper laniaries from the contiguous incisors, and the lower laniaries are removed by a smaller interval from the contiguous *bicuspides;* these intervals admit the

apices of the large laniaries respectively of the opposite jaw, when the mouth is closed.

In the description of all these peculiarities of the skull of the *Chimpanzee*, I have been somewhat lengthy, wishing to give an abstract of the excellent paper by OWEN*; and I deemed it necessary to do so, because the *Chimpanzee* may be considered as the typical link of a chain uniting mankind with the lower animals. By the minute exhibition of all its characters, it is evident that it has a great deal of analogy with the form of *man*, but that, on the other side, it is removed from *man* by its more imperfect structure. This inferiority becomes gradually more apparent in the skull of the other monkeys, as may be seen by the brief statement of their principal forms.

In the skull of the *Orang-œtan* (*fig.* 117)

Fig. 117.

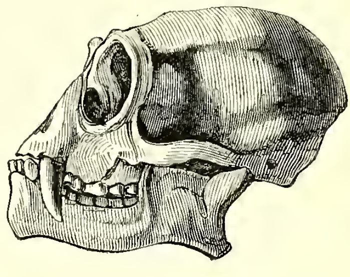


Skull of the Orang-œtan. (*After Owen.*)

the approximation to the *Carnivora* appears principally in the interparietal and occipital crests, which, as I have proved in my *Rech. d'Anat. Comp. sur le Chimpansé*, increases with the general growth of the animal; in the less large interorbital space; in the sometimes single, sometimes double nasal bone, which never projects, as in the *Chimpanzee*, beyond the plane of the nasal process of the superior maxillary bones; in the facial suture of the intermaxillary bone, remaining till the permanent teeth are almost fully developed; in the more prominent maxillary and intermaxillary bones; in the stronger teeth; in the higher and longer lower jaw; and in the more depressed chin. It is remarkable that the analogy with the human form is more striking in the young than in the old *Chimpanzee* and *Orang-œtan*. In the old, the face, and principally the maxillary bones, grow larger, by which the brutish appearance of the skull becomes greater. On the first aspect, this seems a deviation from a general rule, but it is not so; for in the human subject similar modifications of the skull by age may be observed. In advancing age the face of the child becomes gradually larger and higher, and the receptacle for the brain proportionally smaller, in the same manner as in the *Orang-œtan*, but in a less degree.

In the skull of the *Siamang* (*fig.* 118), the

Fig. 118.



Skull of the Siamang. (*Original from the museum of Prof. G. Vrolik.*)

analogy with the human form is, in some parts, greater than in the *Orang-œtan*. The superciliary ridges, and the semicircular boundary for the insertion of the temporal muscle, are much developed, and the skull is very flat, as in the *Chimpanzee*, but the interorbital space is large, as in the human subject; the nasal bone is double in young animals, single in the old, but much broader than in the *Chimpanzee* or *Orang-œtan;* the facial part of the skull is broad, and not so prominent as in the two preceding species; the chin has a vertical direction and rounded form; the coronoidal apophysis of the lower jaw is not very high. By all this the skull of the *Siamang* approaches to that of the human subject, but it shows nevertheless its inferiority by the *foramen occipitale magnum* being placed more backwards. In this and the other *Gibbons* a striking character is given, by the swollen appearance of the posterior wall of the orbit, produced by the convexity of the orbital part of the zygomatic bone. The *ala magna* of the sphenoid bone contributes nothing to the formation of the orbit, being bent backwards. The superior margin of the squamous portion of the temporal bone is straight, as in the *Chimpanzee*, the *Orang-œtan*, and, in general, as in all the monkeys.

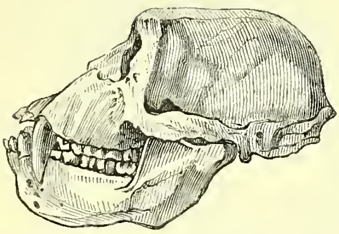
The *Semnopitheci* form a sort of transition from these anthropomorphous species to the lower monkeys. Their face is not very prominent; the facial suture of the intermaxillary bone continues to exist in the adult, but disappears in the very old; the coronal suture is prolonged in a point between the two parietal

* Fearing I might give an inaccurate account, I have employed, for the most part, the very words of that experienced anatomist, feeling persuaded that, especially for a foreigner, it would be difficult to give a more elegant and more accurate description than he has done. I confess myself guilty of the same plagiarism in some other points of the osteology of the *Chimpanzee* and *Orang-œtan*.

bones, and meets there the sagittal suture, which is evidently a proof of inferiority, as A. G. Otto indicated a few years ago.* The depressed chin, the narrowness of the inter-orbital space, the single nasal bone in most of the genus, are the other characters by which the *Semnopitheci* show their lower rank in the animal kingdom.

This lower rank, however, is much more evident in the *Inui*, in which the prominent bony muzzle, the elevated superciliary ridges, the depressed forehead, the flat receptacle for the brain, the chin falling backwards, the long and narrow palate, the single nasal bone, approach to the form of many Carnivora, and manifest an evident inferiority. The facial suture of the intermaxillary σone disappears only in the very old ones. All this is still more apparent in the *Inuus sylvanus* (*fig.* 119),

Fig. 119.

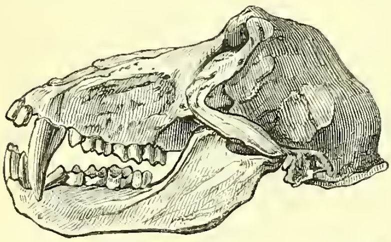


Skull of Inuus sylvanus. (Original, Mus. Zool. Soc. Amsterdam.)

in which the face is more flat and the chin more depressed than in the other species. In the skull of an adult, I found the facial suture of the intermaxillary bone almost obliterated.

In no monkeys, after all, the expression of animality is more distinct than in the *Cynocephali* (*fig.* 120), in which the contracted fore-

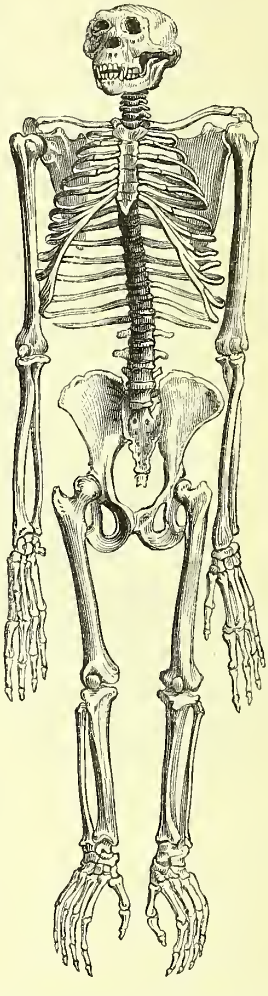
Fig. 120.



Skull of Cynocephalus porcarius. (Original, Mus. G. Vrolik.)

head, the flattened occiput, the formidable canine teeth, the huge jaws, the strong expanded zygomatic arches, the largely developed cranial ridges, the projecting superciliar tuberosities, and the small extension of the cerebral cavity, contribute to form a hideous aspect, principally in the *Mandrill*, in which the convex supermaxillary ridges give an additional feature to their ferocious appearance. For the description of the skeleton of the monkeys of the old world, we shall select the two extremes, the *Chimpanzee* and the *Mandrill*, (*figs.* 121 and 122). The vertebral column of

Fig. 121.



Skeleton of the Chimpanzee. (After Owen.)

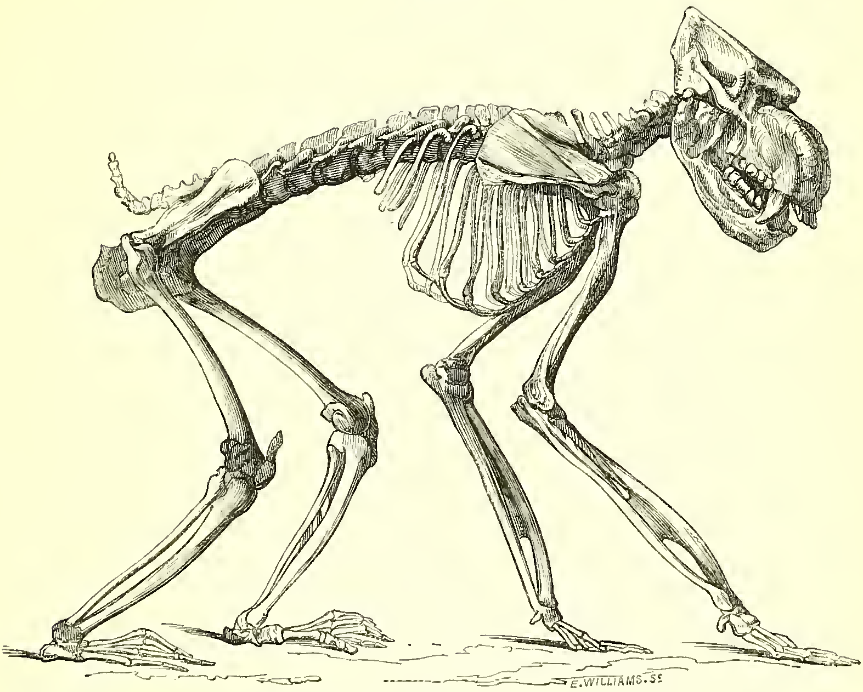
the *Chimpanzee* presents but few deviations from that of the human subject. The number of true *vertebræ* is the same, but an additional pair of ribs takes one from the lumbar, to be added to the dorsal or costal series. The spines of the seven cervical vertebræ are simple and elongated, not short and bifurcated as in the human subject; that of the third *vertebra* is the shortest, with the exception of the atlas, where the spine is wanting. The bodies of the lumbar *vertebræ* are proportionally smaller in the *Chimpanzee* than in *man*, where they are enlarged in reference to his erect position. This difference from the bi-

* A. G. Otto, De rarioribus quibusdam Sceleti humani cum Animalium Sceleto Analogiis. Vratislaviæ, 1839, p. 9.

manous type is manifested still more strongly by the narrowness and length of the *sacrum*, its smaller curvature, and its parallelism with the spine. A peculiarity is observable in the position of the last lumbar vertebra with relation to the iliac bones; these rise on either side to, and are partially joined with that *vertebra*, so that it might almost be reckoned as belonging to the sacral series.

The false *vertebræ*, viz. the sacral and coccygeal, are seven in number. Of these, only the first two have their transverse processes fully developed, and united to the iliac bones; and hence the trunk is less firmly connected with the pelvic arch, and is consequently more in need of additional support from the anterior extremities than in *man*. This peculiarity, together with the general disposition of the vertebral column of the *Chimpanzee*, shows that the animal is not designed to walk, as the human subject, on his hinder legs, but that it is chiefly a quadruped.

Fig. 122.



Skeleton of the Mandrill. (*Original, Mus. Zool. Soc. Amsterdam.*)

In the same way, the pelvis of the *Chimpanzee* differs from that of *man* in all those particulars which characterise the *Quadrumana*, and which relate to the imperfection of their means of maintaining the erect position. The iliac bones are long, straight, and expanded above the outside, but narrow in proportion to their length; the posterior surface is concave, for the location of the glutæi muscles; the anterior surface nearly flat, and stretching outwards, almost parallel with the plane of the sacrum. The whole pelvis is placed more in a line with the spine, than in *man*; its superior aperture is elongated and narrow, so that the whole of the *sacrum* and *coccyx* is visible on a front view. The tuberosities of the ischia are broad, thick, and curved outwards. The pubic bones are broad and deep, but flattened from before backwards. In this general conformity with the quadrumanous type, there is, however, a provision for a more extended adherence of the glutæi muscles in a greater breadth of the *ilia*, between the superior spinous processes, which also incline forwards more than is observable in the lower genera of *Simiæ*; and it may thence be inferred that the semi-erect position is the most easily maintained in the *Chimpanzee*.

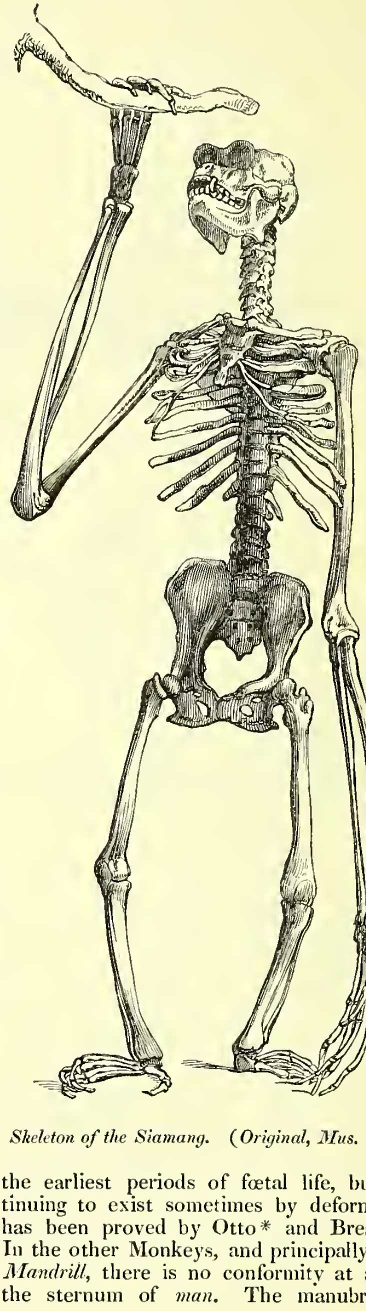
In the *Mandrill* the general disposition of the vertebral column is much more remote from the form of *man*, and approximates to the form of the Carnivorous Mammalia. In the cervical vertebræ, the transverse processes have a triangular form, and offer anteriorly a vertical ridge similar to that which appears in most of the Mammalia as a distinct apophysis. In the dorsal vertebræ, the spinal processes of the nine anterior are inclined backwards, of the three posterior forwards: consequently they offer an opposite direction, which is wanted in the vertebral column of the human subject and in the higher genera of monkeys, but which exists generally in the

four-footed Mammalia. The same analogy with these appears in the disposition of the lumbar vertebræ. Their number is six or seven, and their articular or oblique processes are bifurcated, and give origin to a styloid process, which serves to increase the strength of the lumbar part of the vertebral column, and is therefore to be found in the greater number of the *quadrupeds*.

There is no true sacrum; but two or three sacral vertebræ, forming a conical series, are separately united to the iliac bones, in the same manner as in the *Carnivora*. The pelvis is much more elongated and cylindrical than in the *Chimpanzee*, and consequently more approximate to the type of the quadrupeds. The iliac bones are very long, but narrow, with a posterior concave, and an anterior convex surface. The pubic symphysis is very long; the ischiatic tuberosities are curved outwards, broad, and form a semicircular surface for the insertion of the ischial callosities, which serve the Mandrills as a secure and commodious seat, when they are disposed to sleep or repose after the violent and fatiguing motions which they habitually execute. By all these peculiarities it is manifest that the *Mandrill* is much more remote from man than the *Chimpanzee*, and a superficial examination of the two skeletons (*figs.* 121 and 122) will be sufficient to show the great difference existing between them.

Between these two extremes are ranged the other genera of Monkeys of the Old World, as I have stated in the above-mentioned book. I take the liberty to refer to it for more details, and principally for the gradual deviation, by which the vertebral column of the *Chimpanzee* passes, by the intermediate forms of the *Orang-œtan*, the *Gibbons*, the *Semnopitheci*, the *Inui*, to that of the *Cynocephali;* but I think it necessary to make an exception for the *Siamang*, because the *anthropo-morphous* disposition is more distinct in this ape than in any other, and even more than in the *Chimpanzee* or *Orang-œtan*. The ascending processes of the superior surfaces of the bodies of the cervical vertebræ; the inclination of the spines from the fourth to the ninth dorsal vertebræ; the number of five lumbar vertebræ; their increasing strength and breadth backwards; the form of their transverse and spinal processes; the true sacrum, and the quite anthropomorphous disposition of the iliac bones, make the vertebral column of the *Siamang* (as may be seen in *fig.* 123) approach the most to that of man. The same conformity with man appears in the sternum of the *Siamang*. It is composed of the same portions as the sternum of *man*, viz. the *manubrium*, the body of the bone, and the *xyphoidal appendix*; but it is proportionally broader and shorter, and the body consists of two symmetrical parts. In the sternum of the *Chimpanzee* there is more analogy with the structure in inferior animals. It has a separate manubrium, wanting the semi-lunar incision of that of man. It is connected with a series of osseous segments, and with a xyphoid appendix. In the *Orang-œtan* all these segments, and sometimes also the manubrium, are separated in two symmetrical parts. Consequently it offers the division proper to the sternum of man, in

Fig. 123.



Skeleton of the Siamang. (*Original, Mus. Vrolik.*)

the earliest periods of fœtal life, but continuing to exist sometimes by deformity, as has been proved by Otto* and Breschet.† In the other Monkeys, and principally in the *Mandrill*, there is no conformity at all with the sternum of *man*. The manubrium is

* Otto, in the above-mentioned pamphlet.

† G. Breschet, Rech. sur différentes pièces du Squelette des Animaux Vertébrés; Ann. de Sc. Natur. Août, 1838.

wanted, and the rest of the sternum composed of as many segments or *sternebræ* (Blainville), as there are true ribs.

The form of the ribs has much analogy in the *anthropo-morphous Apes* with the ribs of *man*. Their number corresponds with that of the dorsal vertebræ; consequently it is 13 in the *Chimpanzee* and in the *Siamang*, 14 in some *Gibbons*, 12 in the *Orang-œtan* and in the greater number of the other species of monkeys. They form a very ample and convex thorax in the *Chimpanzee*, the *Orang-œtan*, and the *Gibbons*, which becomes gradually more narrow and compressed in the *Semnopitheci*, the *Inui*, and *Cynocephali*. In the size and length of the anterior extremities, the *Orang-œtan* and the *Siamang* are remote from man, to whom the *Chimpanzee* approaches a little more. In the *Orang-œtan* and in the *Siamang* they are so long that they touch the ground, and in the quadruped position of the trunk the *Orang-œtan* is forced to curve the hands outwards, and to support itself upon their dorsal surfaces. In the *Chimpanzee*, sustaining himself in a semi-erect position, they touch the superior third part of the *fibula*. In the erect position of man they descend not lower than the third inferior part of the thigh. Consequently the *Chimpanzee*, the *Orang-œtan*, and the *Gibbons*, exhibit, as permanent conditions, proportions of the posterior extremities, which in the human subject are transitory, and proper to the early periods of fœtal life. It is, however, according to the observations of Owen, a remarkable fact, that in the young *Chimpanzee* the lower extremities, instead of being shorter, in relation to the trunk, are longer, their adult proportions arising from the increased development of the trunk and anterior extremities, which are thus made fit for the vigorous acts of climbing.

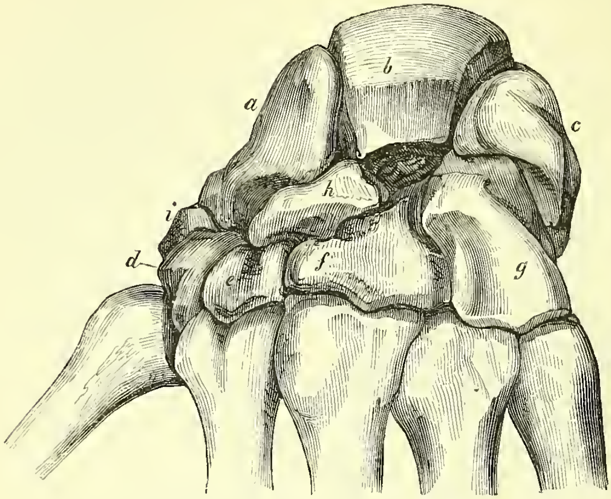
In the *Chimpanzee* the clavicle exhibits the same sigmoid curve as in *man*, but the *scapula* deviates from the human form by being narrower, in proportion to its length, by the spine running more in the direction of the axis of the trunk, and by being situated more towards the middle of the *scapula*, and more perpendicular to its plane. The acromion process is longer and narrower than in man. In the *Orang-œtan* the scapula is broader and more analogous to the scapula of man, but its spine is inclined towards the superior costa; its acromion is narrower and claviform, and its coracoid process has a greater inclination downwards. This inclination is an indication of inferiority manifested in all the lower species of monkeys, but it is wanted in the *Chimpanzee* and in the *Gibbons*, in which the coracoid process has the same direction as in man. That it is an indication of being placed on a lower scale is proved by the fact, that in all the Mammalia with clavicles the same disposition is observed. The humerus is long in the *Chimpanzee*, and in all the other long-armed *Apes*, in which also the fore-arm is longer than the humerus, and composed of two bones, *radius* and *ulna*, curved in two opposite directions, so that the space existing between them becomes very large. In the *Mandrill*, and all the other monkeys of the Old World, the disproportion between the anterior and posterior extremities exists no more; or if there is a disproportion, it is produced by the greater length of the posterior extremities. The humerus and forearm are in them almost of the same length. The hand of the *Chimpanzee* is composed of the same number of bones as the hand of *man*; but the *trapezium* and *trapezoides* are proportionally smaller, while the *os pisiforme* is of larger dimensions, being nearly equal to the *os magnum*. The small size of the *trapezium* evidently relates to the shortness of the thumb, which it supports. The little finger is also shorter, as compared with the other fingers, than in the human subject. The metacarpal bones are chiefly remarkable for their length; the phalanges, both for their length and their interior curvature. The hand is thus admirably formed for clasping the thick boughs of forest trees. On the sides of the anterior surfaces of the first and second phalanges, there are ridges for the insertion of the ligaments for the tendons.

The general opinion is, that the *carpus* of the *Orang-œtan* offers the same number of bones as in man and in the *Chimpanzee*; but I have proved in my *Rech. d'Anatomie comparée sur le Chimpansé*, that there is in the *Orang-œtan* an additional bone, situated between the two series of carpal bones (*fig.* 124.), which I found also in the *Gibbons*, and which seems to exist in all the lower monkeys. De Blainville has described it by the name of *os intermédiaire*. Its existence in the *Orang-œtan*, and its absence in the *Chimpanzee*, are facts of some importance, as they prove that also in this point of organisation the *Chimpanzee* is superior to the *Orang-œtan*.

Another character of the hand of the *Orang-œtan*, and of all the other Monkeys of the Old World, is the length and the narrowness of the metacarpus, and the length of the digital phalanges, with the comparative shortness and backward position of the thumb. The sole exception I know is in the *Siamang*, whose hand represents almost the hand of man, on a more elongated scale. The *trapezium* is not situated on the same level as the other bones of the carpus; consequently the thumb, the bones of which are comparatively longer and thicker than in the *Chimpanzee* or *Orang-œtan*, can be opposed to the other fingers. The middle finger is the longest, and the metacarpal bones decrease from the index to the little finger in the same manner as in *man*. In the *Mandrill*, on the contrary, the four metacarpal bones of the fingers are of the same length, and the middle finger is not longer than the other. Thereby the forehand loses all its analogy with the hand of *man*, and approaches to the form of the paws in the *Carnivora*. In the *Semnopitheci* the thumbs offer a disproportionate shortness, which scarcely surpass the rudimentary form, and prepare us in some

degree to anticipate its total absence in the *Colobi*. This defect necessarily impairs the function of prehension in the *Semnopitheci*, and, according to the views of Ogilby, helps to account for that sedateness of character and indisposition to violent activity for which they are so remarkable.

Fig. 124.



Carpus of the Orang-œtan. (*W. Vrolik.*)

a, scaphoid; *b*, semilunar; *c*, triquetrum; *d*, trapezium; *e*, trapezoides; *f*, os magnum; *g*, unciform; *h*, *intermédiaire* bone; *i*, os sesamoideum for the tendon of the *abductor tongus potticis.*

The femur of the *Chimpanzee* is slightly bent in the anterior direction, as in the human subject; the neck of the bone has the same comparative length, but stands out more obliquely to the shaft. The whole of the bone is flatter or more compressed from before backwards. The head of the femur is attached to the acetabulum by the *ligamentum teres*, which is most remarkable, because it is wanting in the *Orang-œtan*, and exists in the other monkeys. The *tibia* in the *Chimpanzee* is proportionally thicker at the upper end, and the *fibula* considerably stronger at the lower end than in *man;* the interosseous space is wider, and the anterior convexity of both bones may be perceived to be slightly increased. The *patellæ* are proportionally smaller. The relative size and position of the tarsal bones more nearly correspond to the same in the human subject than is found in any other *quadrumanous* animals; but they deviate nevertheless as much as is necessary to produce that position of the foot which is adopted for climbing, viz. on the exterior edge of the foot, with the sole bent up, and inwards. The *os calcis* is relatively weak, as compared with that of man, being more compressed from one side to the other, and smaller in all its dimensions; but it projects backwards more than in the *Orang-œtan* or in the lower *Simiæ*. From the inclination of the *tarsus* to rest on its outer edge, the *os naviculare* is further developed downwards, so as to project considerably below the bones of the same row, without inconvenience from pressure on the sole. The internal cuneiform bone has a corresponding inclination, and thus the hallux is attached to the tarsus, in a position best adapted for its being opposed against the other toes. The whole foot of the *Chimpanzee* is relatively longer and narrower than in *man;* and the digital phalanges are more inflected towards the sole. All these deviations are still more apparent in the *Orang-œtan*, as I have stated in my *Recherches d'Anatomie comp. sur le Chimpansé*; in which I compared the anatomical disposition and the physiological action of the foot of the *Orang-œtan* with those of *club-foot* (*pes varus*). There can be no doubt that this direction of the foot renders it unfit to support the animal upon a level surface, while it is on the contrary very convenient for the action of climbing. For the same reason the hallux or the thumb of the posterior extremities has a great deal of mobility. I saw many times the two *Orangs-œtan* of our gardens at Amsterdam grasp objects with the hinder hand, scarcely with less agility and ability than with the forehand. The frequency of these movements of the hinder thumb, and the friction it has to support, when the animal climbs, seem to be the cause why its nail and ungual phalanx sometimes become atrophied, as I have proved by many examples, and as may be concluded also from the perusal of the works of Camper, Temminck, Owen, Vosmaer, and Oskamp.

In the *Siamang*, and in the other *Gibbons*, the foot approaches more to the human than in the *Chimpanzee* and *Orang-œtan*. The

calcaneum is very strong, and the hinder thumb is, like the hallux of man, the thickest of all the toes. In the other monkeys of the Old World, the hinder hand loses entirely its analogy with the foot of the human subject. The tarsus is long and narrow, and the hallux acquires more and more the form of a small thumb, removed from the other toes, and giving to the foot some resemblance with the hand; from which the name of *four-handed Mammalia* or *Quadrumana* is derived.

Myology.—If the osteology of the Monkeys of the Old World affords us the opportunity of making some interesting remarks, their myology will certainly seem not less important. But it will be almost impossible to give an accurate description of their muscles in the small space allowed to me. I therefore think it proper to confine myself to those statements, by which the same gradual inferiority as in the bony framework may be confirmed, and I beg leave to refer to my *Rech. d'Anat. comp. sur le Chimpansé* for a more minute description. One of the very striking peculiarities of the myology of the monkeys is the existence of a distinct *platysma myoides*, which I found in all those I had the opportunity to dissect. It is an important conformity with the structure of *man*, in whom this muscle represents the larger subcutaneous muscles of the other mammalia.

The *sterno cleido-mastoideus* offers an incipient indication of a lower station, by the clavicular fascicle being wanting in the *Inui* and the *Cynocephali*.

In the *digastricus maxillæ inferioris* there is, especially in the *Inui* and *Cynocephali*, a reunion between the two anterior fascicles or *ventres*, by which the power of the muscle for the abduction of the lower jaw must be strongly augmented. The other muscles situated between the hyoid and the chin resemble in the *Chimpanzee*, those of man, but in the other monkeys they show marks of a lower organisation. According to the observations of E. Burdach and myself, the *hyo-thyreoideus* and *hyo-glossus* are united in one, in the *Inui* and the *Cynocephali*.

In the infra-hyoidian muscles, the only difference from man is, that the intermediate tendon of the *omo-hyoideus*, which exists in the *Chimpanzee* as in man, disappears in the *Inui* and in the *Cynocephali*, and that in these monkeys the inferior portions of the *sterno-hyoidei* and *sterno-thyroidei* are united together. In the *latissimus dorsi*, an interesting transition to the form of the other mammalia is observed, even in the *Chimpanzee*, by a prolongation attached to the olecranon. It seems connected with the power that must be performed by this muscle, in the action of climbing. According to my observations in various animals, the insertion of this prolongation differs according to the variety of movements, performed by the anterior extremities.

The *rhomboideus* of the *Chimpanzee* has the same form and situation as in man, but in the *Inui* and the *Cynocephali* it goes to the occiput, in which its insertion serves to sustain the head, in the quadruped progressive motion of these animals.

In the *Inui* and in the *Cynocephali*, but not in the *Chimpanzee*, there is a conformity with the form of the large *Carnivora*, in the existence of the *acromio-trachelien* (Cuv.), *acromio-basilaire* (Vicq d'Azyr), coming from the transverse processes of the first cervical vertebræ, and inserted into the spine of the scapula. Its function seems to be to bring the scapula more strongly forwards.

The *pectoralis magnus*, *p. brevis*, *subclavius*, and *serratus anticus magnus* of the *Chimpanzee*, the *Orang-œtan*, and the *Gibbons*, resemble those of man. The only difference is that, according to the observations of Sandifort, the *pectoralis magnus* is divided in the adult *Orang-œtan* into a large number of fascicles, in the intervals of which are situated the digitiform prolongations of the enormous laryngeal pouch. But in the *Mandrill* the *pectoralis magnus* acquires more analogy with the large quadrupeds, by its greater extension, and its separation into three great fascicles, of which one comes from the posterior part of the thorax. In the muscles of the anterior extremities the general distribution and form are the same as in man. An interesting deviation is given by the *Hylobates leuciscus*, in which the *caput breve m. bicipitis* takes origin, from the insertion of the *pectoralis magnus*. Can this peculiarity be connected with the velocity of their movements, when they swing themselves from one branch to another? Duvaucel affirms that they will on these occasions leap, with comparative ease, to the surprising distance of forty or fifty feet. About the *extensores* of the fingers, a lower form may be observed in the *extensor digiti indicis*, or *m. indicator*, which is not a separate muscle, but only a portion of the *extensor communis*. Consequently the fore-finger, or *index*, must want the so characteristic separate movements, by which we are accustomed to call the attention upon a subject. The imperfection of this muscle is certainly in relation with the lower psychical condition of the animal. In the *Inui* and the *Mandrill* the extensores are still more imperfect, by the division of the *extensor digiti minimi*, which gives a tendinous insertion to the annular or fourth finger. It is, as I showed in my work upon the *Chimpanzee*, a transition to the form of the Carnivora. The eight muscles of the thumb exist in the *Chimpanzee* and in the *Hylobates leuciscus*; but in the *Orang-œtan* and in the *Mandrill* the *abductor longus* and the *extensor brevis pollicis* are united in their muscular portions, while the tendons remain separate, and in the *Inui* there is but one muscle, giving two tendons, which are united at their extremities. This is a distinct transition to the form of the *Carnivora*. I have found this single muscle in all those which possess a thumb. The small muscles of the thumb, viz. the *abductor brevis*, the *flexor brevis*, the *adductor*, and the *opponens*, exist in all the monkeys of the Old World, but on a smaller scale than in *man*. They have also

the three small muscles for the little finger on the opposite edge of the hand. The consequence of all this is, that the hand of the monkeys of the Old World approaches to the perfection of the human hand, from which it differs by the length and the narrowness of the palm of the hand, the length of the fingers, the backward position of the imperfect thumb, and a less variety of movements. For the physiological results which can be derived from this difference, I refer to my *Rech. d'Anat. comp. sur le Chimpansé*, p. 34. The muscles of the posterior extremities differ more from those of the human subject. The *glutæi* are feeble, and inserted very low on the femur; the *gracilis* is much broader than in *man*, and inserted very low in the tibia; the same is the case with the *semitendinosus*, the *semimembranosus*, and the *biceps femoris*. The result of this low insertion must be, that the knee can only be maintained in a bent, and consequently the trunk in a semi-erect attitude.

The *gastrocnemius* and *solæus* remain separate until their insertion in the calcaneum, where they unite to form one tendon. They are flatter than in *man*, and consequently do not form the calf of the leg, which is so characteristic in *man*.

There is a *plantaris*, as in *man*. The monkeys seem to be the only brute animals which possess it.

The *flexor magnus* of the great toe or thumb of the posterior extremities is not confined to this toe, but gives tendons to the other toes. Consequently it combines its action with that of the *flexor magnus 4 digit. pedis*. The monkeys possess also a *flexor brevis, lumbricales,* an *abductor* and *adductor hallucis*, a *flexor brevis, adductor brevis digiti minimi, peronæus longus* and *brevis*, and *tibialis posticus*. All the muscles on the sole of the foot are more isolated than in *man*, and consequently they produce more distinct and separate movements for the digits, and principally for the hinder thumb.

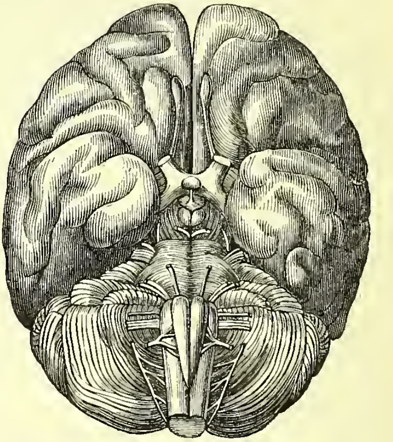
They have no *peronæus tertius*, but the *tibialis anticus* differs from the same in *man*, by its separation into two fascicles, of which the inner seems to act as a *tibialis anticus*, while the outer is a long *abductor hallucis*. I found this disposition in all the monkeys I had the opportunity to dissect, and it is also confirmed by the observations of E. Burdach.

The last myological peculiarity which I shall mention is, that the tendon of the *extensor communis longus quatuor digitorum* is surrounded and fixed by a ligamentous loop, about which I can add the historical peculiarity, that this ligament, hitherto unknown, has been described in the same year, and perhaps in the same month, by A. Retzius in Stockholm, and by myself in Amsterdam.*

* A. Retzius, Bemerk. ueb. ein Schleuderformiges Band in dem Sinus tarsi des Menschen u. mehrere Thiere in J. Muller, Arch. Berlin, Jahrg. 1841, Th. v. p. 497. W. Vrolik, Rech. d'Anat. Comp. sur le Chimpansé, p. 22. tab. v. fig. 2.

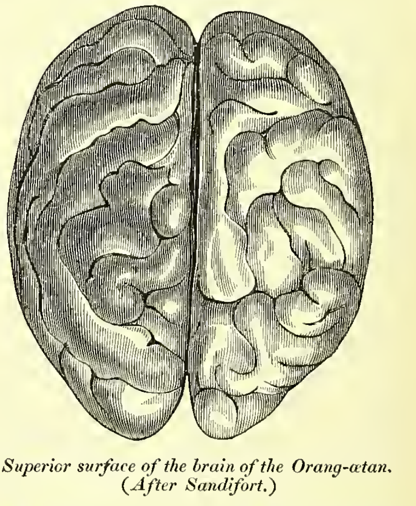
Neurology. — The brain of the monkeys of the Old World represents an imperfect outline of the brain of *man*. By the form and the number of convolutions, Leuret* proved that it approaches to the brain of the human subject; but however great this analogy may be, there remains, however, no doubt that there are some typical differences between the brain of man and of the monkeys, and that from the *Chimpanzee* to the *Cynocephali*, the gradual tendency to inferiority is as manifest as in the other points of organisation. We still want perfect representations of the brain of the first, but we may supply this defect by drawings of the brain of the *Orang-œtan*, of which Tiedemann has represented the basis, Sandifort the superior surface, and I a vertical section. (*Figs*. 125, 126, 127.) If we

Fig. 125.



Basis of the brain of the Orang-œtan.
(After Tiedemann.)

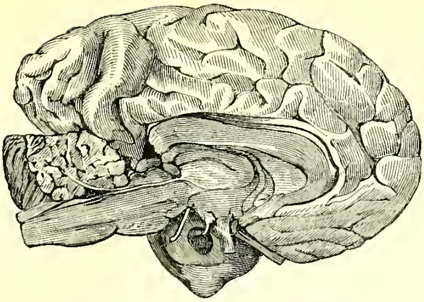
Fig. 126.



Superior surface of the brain of the Orang-œtan.
(After Sandifort.)

* F. Leuret, Anat. Comp. du Système nerveux considéré dans ses rapports avec l'intelligence. Paris, 1839, 8vo.

Fig. 127.



Vertical section of the brain of the Orang-œtan. (*After W. Vrolik.*)

compare these distinct views of the brain of the *Orang-œtan* with those of the Baboon represented by LEURET * (*figs.* 128, 129, 130), the inferiority of these to the *Orang-œtan* is so manifest, that it needs scarcely any further explanation. In the first instance, it appears that the brain of the *Cynocephalus*, and, according to the observations of TIEDEMANN, we could say the same for all the monkeys inferior to the *Chimpanzee*, the *Orang-œtan*, and the *Gibbons*, differs from the brain of man :

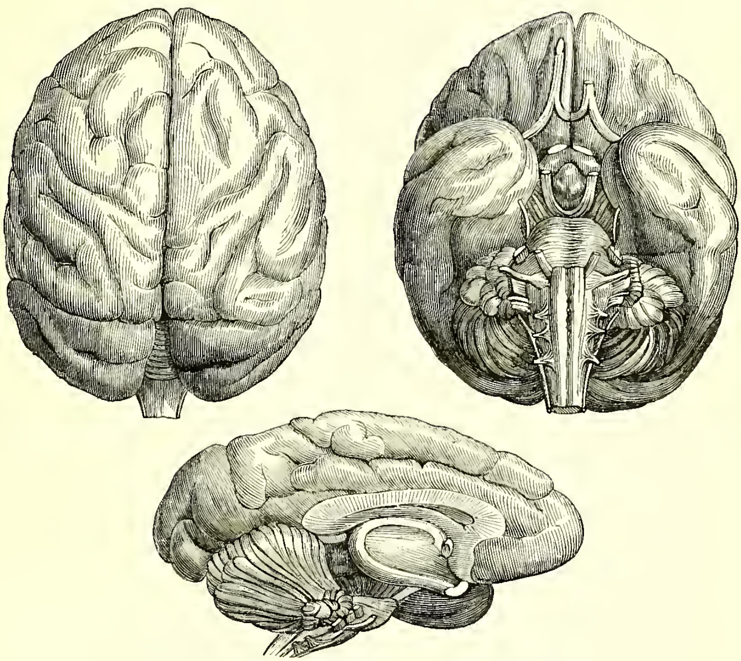
1. By a greater breadth in proportion to the length, and consequently by a less elliptical and more triangular form.

2. By less development of the hemispheres of the brain, which do not cover the whole cerebellum.

3. By a smaller number and greater symmetry of the convolutions, and less deep anfractuosities.

4. By less development of the *corpus striatum*, *thalamus nervorum opticorum*, *corpus callosum*, and *septum lucidum*.

Figs. 128, 129, 130.



Views of the brain of the Baboon. (*After Leuret.*)

5. By the want of digitations on the convex margin of the *cornu Ammonis*.

6. By the want of the *eminentia digitalis* (*pes Hippocampi minor*).

7. By the disposition of the *corpora albicantia*, which are united in one mass.

8. By the absence of calculous granulations in the *glandula pinealis*.

9. By less development of the *cerebellum* and of the *pons* VAROLII.

All these manifestations of inferiority are not so distinct in the brain of the *Orang-œtan*, which approaches more to that of *man*. This approximation consists in :

1. The more elliptic, and consequently more human-like form of the brain. It is a most interesting fact, that the deviation, in the descending line, begins already in the *Gibbons*, the brain of which has a more triangular form, and less developed anterior lobes, than the brain of the *Orang-œtan*.

2. The larger cerebral hemispheres, which are protracted behind the cerebellum.

* F. Leuret, Anat. Comp. du Système nerveux considéré dans ses rapports avec l'intelligenee, Paris, 1839, 8vo.

3. The existence of two separate *corpora mammillaria*, which I found also in the *Hylobates leuciscus*, and which SANDIFORT represented in the *Siamang*. But they are in these less developed than in the *Orang-œtan*.

4. The presence of digitations on the *cornu Ammonis*.

5. More numerous convolutions and deeper anfractuosities.

6. A larger cerebellum.

In all these peculiarities, the brain of the *Orang-œtan* is superior to that of other monkeys, and still more so to that of the *Gibbons*, which offer otherwise so much analogy with it. The plate of SANDIFORT, representing the brain of the *Siamang*, and my dissection of the *Hylobates leuciscus*, have proved, that in the *Gibbons* the convolutions are not so numerous; the anfractuosities not so deep, their symmetry greater; the cerebral hemispheres less developed; the cerebellum smaller; the *pons* VAROLII less distinct; the *cornu Ammonis* without digitations. This greater perfection of the brain of the *Orang-œtan* is evidently in accordance with the more eminent intellectual faculties of the *Orang-œtan*, while, according to the observations of DUVAUCEL and of S. MULLER, the *Siamang* and the other *Gibbons* are very stupid. But if, on one side, this superiority of the brain of the *Orang-œtan*, with which the *Chimpanzee* seems to have a great deal of analogy, cannot be a subject of controversy amongst anatomists, they would however go too far by saying, that the brain of both is in all points similar to that of man. The following differences may be indicated:

1. The mass of the brain, in proportion to the volume of the body, is less in these Apes than in *Man*.

2. The cerebral hemispheres are less developed, and not so much protracted backwards.

3. The nerves are thicker in proportion to the circumference of the brain.

4. The convolutions are not so numerous, and the anfractuosities less deep.

5. The *corpus callosum* is not so much extended backwards.

About the nerves of the Monkeys, I shall but mention one very interesting modification, which I observed in the *nervus accessorius* WILLISII of the *Chimpanzee*. It is divided into two branches, as in *man*, but the internal is not united with the *vagus*, as it penetrates separately into the larynx. This very peculiar ramification seems to confirm the opinion of BISCHOFF*, that the internal branch of the *n. accessorius* WILLISII forms partly the *n. laryngeus superior*. About the organs of sense there is not much to say. The eye approaches much to the eye of the human subject, by the existence of the yellow spot on the retina, but it differs by a more thin sclerotica. The ears of the higher order of monkeys resemble much the same organs in the human subject, from which they differ only by a less developed *lobulus*. The tongue is short, broad, and round, as in *man*, but it becomes long and narrow in the *Inui*, and still more so in the *Cynocephali*.

ANGEIOLOGY. — In the distribution of the vessels and the form of the heart, the monkeys of the Old World offer a great analogy with the disposition of the same parts in the human subject. But few differences can be mentioned. In the trunks arising from the *arcus aortæ*, the superior order of monkeys, as the *Chimpanzee* and adult *Orang-œtan*, offer the same number and distribution as in *Man*; but in the *Semnopitheci*, the *Macaci*, and *Cynocephali*, there is a commencement of a descending scale in the disposition of the A. innominata, which divides into three branches, viz.. the right *subclavian* and the two carotids, in the same manner as in the *Marsupials* and *Carnivora*. It is interesting, that I found also this distribution in four young *Orangs-œtan*, but that Sandifort observed in the adult the human-like division. In the other ramifications, the resemblance to those of man is very great. The plates of descriptive anatomy which I published on the *Chimpanzee*, will be sufficient to prove the truth of this assertion.

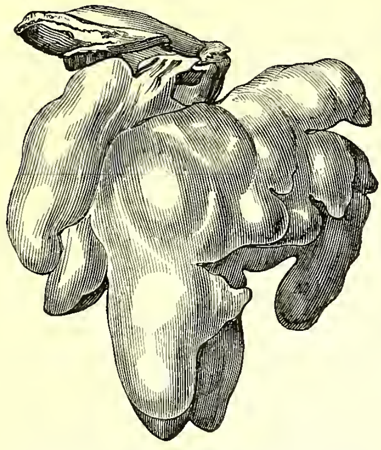
SPLANCHNOLOGY. — No parts of the anatomy of the monkeys are, perhaps, more interesting than the pouches of the larynx. I have published a great number of observations about them, by which is proved: 1. that they exist in the *Chimpanzee*, the *Orang-œtan*, the *Siamang*, the *Semnopitheci*, *Cercopitheci*, *Inui*, and the *Cynocephali*; 2. that they are larger in the males than in the females; 3. that they grow with the age of the animal, and are consequently the largest in the most aged; 4. that they are chiefly a dilatation of the laryngeal ventricles in the *Chimpanzee* and in the *Orang-œtan*, but that in the other monkeys they are in direct communication with the cavity of the larynx, by an aperture at the basis of the epiglottis; 5. and that they are wanting in the *Gibbons*, the *Cercopithecus radiatus*, the *Cercopithecus mona* and *Cynocephalus porcarius*. It is very difficult to derive any physiological conclusion from all these anatomical statements. The most probable hypothesis seems to be, that these receptacles of air, which send their prolongations between all the muscular fascicles (*fig.* 131), seem to diminish the specific gravity of the body, in the action of climbing, and that they are consequently passive organs of movement. I have offered this opinion in greater detail in my work upon the *Chimpanzee*, and I refuted there the opinion that they were connected with the utterance of voice. The other parts of the laryngeal apparatus do not differ much from those of *man*, with the exception of the hyoid bone, which has much of the human form in the *Chimpanzee*, in the *Orang-œtan*, and in the *Gibbons*, but the basis of which is changed into a convex and elongated shield in the other monkeys, in which the laryngeal pouch opens below the epiglottis.

In the form and structure of the heart and the lungs, there is no difference between the

* L. W. T. Bischoff, Nervi accessorii Willisii, Anat. et Physiol. Darmstadii, 1832.

monkeys of the Old World and the human subject.

Fig. 131.



Laryngeal pouch of the adult Orang-œtan. (*After Sandifort.*)

In the organs of digestion, there is much difference to be observed in the various species of monkeys. The *Apes*, viz. the *Chimpanzee*, the *Orang-œtan*, and the *Gibbons*, offer much resemblance in these organs to those of *man*. The stomachs of the four young *Orangs-œtan*, which I dissected, had quite the human form and structure. But in the adult described by Sandifort, the pyloric portion is separated from the cardiac by a very narrow constriction, and the tunics of the pyloric portion are very thick. In the cœcum the resemblance to *man* is still more striking, by the existence of a vermiform appendix, which is separated from the intestine by a constriction in the *Chimpanzee*, is continuous with the intestine in the *Orang-œtan*, and is very small, and almost rudimental, in the *Gibbons*. Consequently there is also a descending gradation in this organ, in the same manner as in all the other points of organisation ; for the appendix is wanting in all the other monkeys, in which the cœcum is moderately large and terminates in an obtuse cone. The stomach of the other species has not the same oblong form in the transverse direction, as the stomach of the *Simiæ* and of *man*, but acquires a more globular form, especially in the *Cynocephali*. In this way it forms a transition to the form of the stomach in the *Carnivora*. A very interesting deviation is afforded by the *Semnopitheci*, in which Wurmb, Otto *, and Owen † found (as I also saw confirmed in the *S. maurus*) a complicated form and construction of the stomach, viz., its division into three portions : 1. cardiac pouch, with smooth parietes, slightly bifid at the extremity ; 2. a middle, very wide, and sacculated portion ; 3. a narrow, elongated canal, sacculated at its commencement, and of simple structure towards its termination. This complication of the stomach seems to be connected with the vegetable food of the *Semnopitheci*, which consists only of fruits, and it is also a repetition of the divisions we find in the stomach of the *Pteropi*, the *Hyrax capensis*, the *Bradypoda*, the *Cetacea*, and in the utmost perfection in the *Ruminantia*. A curious fact connected with this sacculated division of the stomach is the existence of bezoars in the *Semnopitheci*. They are said to be smaller and rounder than those produced by the goats, gazelles, and antelopes.

A similar disposition of the stomach exists in the *Colobi*. Ruppell observed it in the *Colobus guereza*, and Owen * said, that in the *Colobus polycomos*, the sacculation of the stomach is produced by the same modification of the muscular fibres as in the *Semnopitheci*, combined with a great extent of the digestive tunics. A narrow band of longitudinal fibres traverses the lesser curvature of the stomach, and a second band, commencing at the left or blind end of the cavity, puckers it up in a succession of sub-globular sacs along the greater end. The form and the size of the cœcum, and the length and disposition of the intestinal canal in the *Colobus*, equally correspond with those parts in the *Semnopitheci*. About the urinary and genital organs there are but few peculiarities to observe in the monkeys of the Old World. The urinary organs have the same general disposition proper to the human subject ; the male genital parts differ only by the existence of an *ossiculum penis*, by the lobulated form of the *glans* in some species, and by the complicated structure and large development of the *vesiculæ seminales*, especially in the *Mandrill*.

In the female organs, the form and structure of the uterus are interesting : it resembles that of *man*, and differs from the divided and *bicorn* uterus of most of the other Mammalia. It is only by a more longitudinal, and we may say a more fœtal form, that the uterus of the monkeys differs from the same organ of the human subject in the adult state ; whereas in gestation, parturition, lactation, and in menstruation, the monkeys of the Old World offer a great deal of analogy with mankind, as may be seen in the elegant descriptions which F. Cuvier gives of many species in his *Hist. Nat. des Mammifères*. In the clitoris there is no bone ; at least Leuckart found none in *Inuus rhesus*, but he observed a bifid clitoris in *Cercopithecus sabæus*. According to the observations of G. Breschet J. van der Hoeven and Schroeder van der Kolk †, the placenta of the monkeys of the

* A. W. Otto, ueber eine neue Affenart, den *Cercopithecus leucoprymnus*, in Nov. Act. Acad. Cæs. Leopold. Carol. Nat. Curios, vol. xii. p. 2.

† R. Owen, on the sacculated form of Stomach as it exists in the Genus *Semnopithecus*. Trans. Zool. Soc. tom. i. p. 65. The paper of Wurmb is to be found in the Memoirs of the Batavian Society.

* R. Owen, Proceedings of the Zoological Society, p. ix. 1841, p. 84.

† Tÿdscheift von Natuurlÿke geschiede nis enphysiologie intgegeven door J. van der Hoeven en W. H. de Vrese, Leyden 1837—1838, &c. &c. p. 357. G. Breschet, Rech. Anat. sur la Gestation des

Old World is separated into two lobes, united by vessels. This may be a transition to the cotyledons of the placenta in most of the Mammalia.

The Second Group of *Simiæ* comprehends those of the New World, or *Cebinæ* (*Simiæ platyrrhinæ* G. S. HIL), possessing a distinct character in the existence of four additional molar teeth, by which the general number of teeth is thirty-six. Their head is distinguished by a more rounded form, by nostrils situated laterally on a large nose. A long, and in some species a prehensile tail; the want of cheek-pouches and of callosities on the buttocks; a smaller and less robust body, and a less malicious but more melancholy character, give a very conspicuous and distinguished physiognomy to this group.

2. CEBINÆ. Monkeys of the New World. The number of teeth is: incisors, $\frac{4}{4}$; canines, $\frac{1-1}{1-1}$; molars, $\frac{6-6}{6-6} = 36$.

They ought to be divided into two great divisions, of which the first comprehends those in which the tail is prehensile, viz., capable of grasping branches, so as to perform the office of a fifth extremity. It is naked at its extremity in some species.

a. *Cebinæ*, with a prehensile tail, naked at its extremity.

1. *First Genus. Mycetes. Alouatte. Singe hurleur*, Fr. *Howler*, Engl. *Brul-aap*, Dutch.

Pyramidal head, with an elevated inferior jaw, whose branches are very distant, to give room for a peculiar inflation of the basis of the hyoid bone, which communicates with the larynx, and seems to produce the loud and frightful howlings. By this the anterior surface of the neck is swollen up, which, added to their long beard, gives these animals a hideous appearance. The teeth have the general disposition proper to the *Cebinæ*, but the canini are very strong, and therefore the space in the upper jaw between the external incisor and canine tooth is large for the reception of the canine tooth of the lower jaw. The *Mycetes* are drowsy and lazy in captivity. In their native woods they live in troops, and climb the trees with much agility.

Spec.— *M. seniculus, M. fuscus, M. niger.*

2. *Second Genus. Ateles. Sapajou ordinaire.*

Rounded head, with a slightly prominent muzzle. The thumb imperfect, but visible in some, not visible in others. The clitoris so much developed, that it has quite the appearance of a penis, with a channel at its inferior surface. Those, who possess a visible thumb, have been considered by SPIX as forming a distinct genus, under the name *Brachytele*, but I think it not necessary to introduce this division. The species of the genus *Ateles* represent in America the *Semnopitheci* of Asia, and the *Colobi* of Africa. They have the same slowness of movement, and the same gravity and gentleness of manners. Their progressive motion upon a level surface is very uneasy and unsteady, while they are forced to sustain themselves upon the internal edges of their fore-hands and the external of their hinder-hands. But they climb with much agility, aiding themselves with the prehensile tail, which acts as a fifth extremity. Their teeth resemble those of the genus *Mycetes*, but the canine are not so strong, and the molar teeth rounder. They all inhabit Guiana and Brazil.

Spec.—*Ateles pentadactylus, A. hypoxanthus, A. paniscus, A. arachnoides, A. fuliginosus, A. marginatus.*

3. *Third Genus. Lagothrix* GEOFFR. *Caparo.*

Rounded head, as in the genus *Ateles*; a thumb, as in *Mycetes*, and the tail naked at its extremity, as in both. This genus is only to be found in South America, and chiefly in Brazil. The hyoid bone is not very large.

Spec. — *Lagothrix Humboldtii, L. canus.*

b. *Cebinæ*, with a prehensile tail covered with hair at its extremity.

4. *Fourth Genus. Cebus. Sajou. Singe pleureur*, French. *Capucyn-Aap*, Dutch.

Rounded head and oval face, with a gentle expression. Tail thicker than in the genus *Mycetes* and *Ateles*, and less prehensile, curled at its extremity, longer than the body. Teeth not so strong as in these, especially the canine. The *Cebi* feed upon fruits. Their movements are graceful and gay. Their manners a mixture of sweetness, cleverness, agility, and lubricity. Their voice is a gentle whistle. The determination of the species has caused great confusion. RENGGER is of opinion, that some of them are merely modifications by age of the same species. They inhabit principally Guiana.

Spec.—*Cebus apella, C. fatuellus, C. robustus, C. xantho-sternos, C. capucinus, C. hypoleucus, C. albifrons.*

5. *Fifth Genus. Callithrix. Sagouine*, Fr.

Slender tail; teeth not prominent, and short canine.* The head more elevated than in *Cebus* and *Pithecia*, but smaller, with less prominent zygomatic arches and higher branches in the lower jaws. Consequently there is more room for the reception of a more complicated larynx. Their voice is heavier, and not so whistling as in the *Cebi* and *Pitheciæ*.

Callithrix personata, C. amicta, C. cuprea, C. melanochir.

One species *C. sciurea*, or *saimiri*, ought to be separated from the rest. WAGNER makes

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Quadrumanes, Mém. de l'Acad. des Sciences, s. xix. Paris, 1845.

* In his book *des Dents des Mammifères considérés comme Caractères Zoologiques*, F. Cuvier gives the teeth of this genus as type for the *Saki*'s by a mistake, which he corrected in art. *Saki noir*, Hist. Nat. d. Mammif. t. iv. edit. in folio.

of it the genus *Chrysothrix*. Its tail is not prehensile, but depressed, and often twisted round objects. Its head is flat; between the two orbits there is but a membranous septum, instead of a bony wall, and the glans penis is round, as in *man*; while it is flat, in the form of the head of a mushroom, in the *Cebi*, which have the penis in continual erection.

6. *Sixth Genus. Nochthora* F. Cuvier. *Aotus* Humboldt. *Dourocouli*.

Differs only from the genus *Callithrix* by large nyctalope eyes and ears, which are partly covered by the skin, and by a small face. The species of this genus have nocturnal habits, and a feline physiognomy. They feed not upon fruit, as the precedent species, but on small birds and insects. In their form, nocturnal habits, and great sensibility to light, the *Nochthoræ* approach very much to the species of the genus *Stenops*, from which they differ in their internal structure. Their nails are straight, long, and sulcated. The dental formula is: incisors $\frac{4}{4}$, canines $\frac{1-1}{1-1}$, molars $\frac{6-6}{6-6}$. They inhabit Brazil.

Spec. — *Nochthora trivirgata*.

7. *Seventh Genus. Pithecia. Saki.*

The characters of this genus consist in the bushy, but short, prehensile, and long tail, the slender body, the large ears, the dense beard in some species, and the straight, but claw-like nails. Their incisor teeth are more prominent than in the genus *Cebus*. Brazil.

Spec. — *Pithecia Satanas*, *P. rufiventris*, *P. leucocephala*, *P. inusta*.

8. *Eighth Genus. Hapale. Ouistiti. Sahui.*

This genus departs more from the typical genera of monkeys of the New World than any other, inasmuch as they have only the same number of teeth as the monkeys of the Old World, viz. 32: incisors $\frac{4}{4}$, canines $\frac{1-1}{1-1}$, molars $\frac{5-5}{5-5}$. The nails, by being compressed and pointed, assume the appearance of claws, except the thumbs of the after-hands, which have flat nails; but the thumbs of the fore-hands, which have no flat nails, are so slightly separated from the other fingers, that it is not without hesitation that the Ouistitis are called *four-handed* or *Quadrumana*. All the species belonging to this genus live in troops in the Brazilian forests, where they spring from bough to bough, more like birds than quadrupeds. They resemble squirrels, whose form they seem to represent in South America, which possesses but one species of squirrels, *Sciurus æstuans*. Their incisors, canini, and false molars, are sharp and acuminated. The inferior incisor teeth are long, narrow, and prominent. They feed upon insects, eggs, birds. Their voice is a gentle whistle, which de Humboldt* compares to the voice of some birds. He says that their larynx is similar to the inferior larynx of birds, but he did not illustrate this opinion by sufficient anatomical details.

The species can be divided into two groups. The first contains those in which the inferior incisors are cylindrical and the tail is annular.

Hapale jacchus, *H. penicillatus*, *H. leucocephalus*.

In the second, the inferior incisors are truncated like the mouthpiece of a pipe, and the tail is not annular.

H. argentatus, *H. midas*, *H. ursulus*, *H. labiatus*, *H. chrysomelas*, *H. rosalia*, *H. chrysopygus*, *H. œdipus*.

Osteology. — If we take a general survey of these eight genera of monkeys of the New World, we may observe in them, as well as in those of the Old World, an indication of the descending line, by which they pass into the form of the *Lemurinæ*, and by those into the *Insectivora*. In this way they constitute a series, which is parallel to that of the monkeys of the Old World, the latter passing into the *Carnivora*, the former into the *Insectivora*. The truth of this assertion will be proved by a more minute examination of the skeleton.

We shall first consider the skull. J. A. Wagner divided the monkeys of the New World by their skull into two great divisions. The first is a pyramidal skull, in which the height is greater than the length, and in which the occiput has no posterior eminence, and the occipital foramen is situated backwards. To this division belong *Mycetes*, as eminently characteristic, and, in subsequent gradation, *Callithrix*, *Nochthora*, *Pithecia*, and *Lagothrix*. The second form of skull is elongated, with a prominent muzzle, a convex occiput, and an occipital foramen, situated at the basis of the skull. Wagner refers to it the *Saimiri*, offering a typical pre-eminence, and subsequently *Hapale*, *Cebus*, and *Ateles*.

In *Mycetes* (*fig.* 132) the forehead is ele-

Fig. 132.

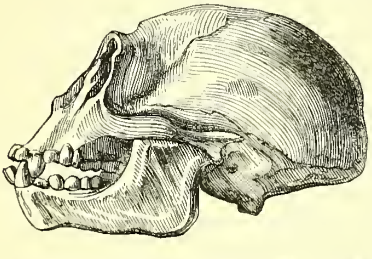
Skull of Mycetes ursinus. (*Original, Mus. Vrolik.*)

vated, the face flat and large; the distance between the two orbits very great; two nasal bones; the chin very depressed; the lower jaw high, with distant branches, between

* A. de Humboldt, Observ. de zoologie et d'anatomie comparée. Paris, 1811, vol. i. p. 8.

which the inflated hyoid bone is situated. The same character is to be found in the genus *Ateles*. In *Mycetes*, *Lagothrix*, and *Callithrix*, there is a peculiar round aperture in the orbital portion of the zygomatic bone, which has the appearance as if it were pierced in the bone by a gimlet. *Mycetes*, *Ateles*, and especially *Callithrix*, afford a very striking conformity with *Hylobates*, in the swollen appearance of the posterior wall of the orbits, produced by the convexity of the orbital part of the zygomatic bone. This is a new addition to the analogy between *Hylobates* and *Ateles*. The *ala magna ossis sphænoidei* is yet more depressed backwards than in *Hylobates*. In *Cebus* (*fig.* 133) the cranium is elongated,

Fig. 133.



Skull of Cebus apetta. (*Original, Mus. Vrolik.*)

and uniformly round. The frontal bone is lengthened to a sharp point, which advances between the two parietals. This is, as I have said before, a manifest indication of a lower rank. The face is not very prominent; there are two nasal bones; a distinct intermaxillary bone; a rounded chin, which recedes. In *Callithrix*, *Pithecia*, and *Nochthora*, the skull has an oblong form, but it resembles very much a small human skull. The single frontal bone has a triangular form, and is distinguished by the convexity of the orbital part. In the *Saimiri* the septum between the orbits is but membranous, and the interorbital space narrow; the nasal bone is sometimes single, sometimes double; the intermaxillary bone distinct; the chin round and prominent; the muzzle not protruding; the orbital part of the zygomatic bone wants the opening proper to *Ateles*, *Mycetes*, *Lagothrix*, and the other species of *Callithrix*. This general resemblance to the human skull is still greater in the *Ouistitis*. The external tuberosity of the orbit is less marked; the interorbital septum is osseous; the muzzle not very prominent; the intermaxillary bone distinct, but obliterated in old age; the nasal bones broad, short, completely separated, and consequently similar to those of man; the chin is depressed, but rounded. Notwithstanding this general resemblance to the skull of *man*, *Cebus*, *Callithrix*, and *Hapale* differ in some essential points from *man*. The forehead is much narrower, and has its greatest elevation not laterally, but in the middle; the occipital foramen placed more backwards; the muzzle more protruding. In the vertebral column of all the *Cebinæ* there is a manifest inferiority to be seen in the disposition of the cervical vertebræ, in which there are anterior ridges at the transverse processes, in the same manner as in the lower Mammalia. In the *Cebi*, the spinal process of the second cervical vertebra offers another analogy with the latter, in its elevated form, in its strength, and in its truncated posterior edge. In the *Saimiri* the tendency to a lower degree of pefection is still greater, by the triangular form of the transverse processes, and in the *Ouistitis* the spinal processes become long, acute, and directed backwards. The number of dorsal vertebræ varies from 13 to 14, and is consequently in general greater than in the monkeys of the Old World. There is opposite direction between the spinal processes of the three last, and the ten or eleven first dorsal vertebræ. The same disposition is observed in the *Saimiri*, but in the *Ouistitis* there is only opposition in the spinal process of the last dorsal vertebra. In *Ateles* and *Cebus* the number of lumbar vertebræ is five. The styloid processes are plainly indicated, but their spinal processes are inclined forwards, and terminate in a recurved point, in the same manner as in the *Carnivora*. In the *Ouistitis* the analogy with the quadruped form is still greater, as the styloid processes are very long. In the *Nochthora* the number of the lumbar vertebræ is eight, by which it approaches to *Stenops*. The sacrum is in the *Cebinæ* a broad quadrangular bone, with acute edges, united only by one of its spurious vertebræ with the iliac bones. Consequently the *symphysis sacro-iliaca* is less firm than in the higher species of monkeys. At least such is the case in the *Cebi*, the *Ouistitis*, and the *Saimiri*; but in *Ateles* I found four spurious sacral vertebræ united with the iliac bones. The iliac bones are in general narrower in the *Cebinæ* than in the monkeys of the Old World: consequently the pelvis has a more cylindrical form, with a very long pubic articulation, and approaches more to the form of the pelvis in the *Carnivora*. The caudal *vertebræ* of the *Cebinæ* deserve a separate mention. They are true or spurious vertebræ. The true are but four or five, short and thick. The spurious are the longest, but become shorter at the extremity of the tail. They are only united by the bodies, not by the articular processes. Chiefly remarkable are the inferior spinal processes in the anterior caudal *vertebræ*, representing the letter V, and forming a canal, in which pass the vessels for the tail. These processes disappear in general in the posterior caudal vertebræ, and in the monkeys with a prehensile tail the posterior vertebræ become round, tubercular bones, imitating a series of small digital phalanges. The thorax of the *Cebinæ* is compressed, and the ribs do not form the posterior arches, by which the back of *man*, of the *Chimpanzee*, and of the *Orang-outan* acquire a broad and flat surface, and by which it is possible for these animals and for *man* to lie at full length on their back. All the

species, on the contrary, which possess ischial callosities, the *Gibbons* among the rest, sleep and repose themselves in a sitting posture, with the arms folded across the knees, and the head reclined upon the breast, or supported by the shoulder. The *Cebinæ*, in which the ischial callosities are wanting, lie down on the lateral surface of their body. The sternum is separated in the *Cebinæ* into as many segments as there are true ribs; consequently it has quite lost the analogy with the human subject, which it has in the higher monkeys of the Old World. In the anterior extremities, the humerus of *Cebus*, *Nochthora*, *Saimiri*, and *Ouistiti*, is similar to that of the *Carnivora*, by an aperture in the internal condyle, serving for the passage of the brachial artery and the median nerve, which are preserved in this manner from compression and injury, by the contraction of the muscles in the climbing motion of these *Quadrumana*. In the carpus of the *Cebinæ* there are nine bones, and consequently they possess the intermediate bone, proper, as I have said, to all the monkeys, with the exception of the *Chimpanzee*. The phalanges of the fingers and the toes are in general very long and incurvated, by which disposition they acquire a greater aptitude to grasp branches of trees, while climbing. In *Ateles* the fore-hand has quite lost its analogy with the hand of man, by the want of the thumb, which is only represented by an imperfect metacarpal bone. In *Ateles hypoxanthus*, which has a rudimental thumb, Prince MAXIMILIAN says that it consists of two phalanges, of which the first is but half as long as the second. In the *Cebi*, the fore-hand differs from the hand of *man*, by the deviation of the thumb, which is situated on the same level as the other fingers, and has the same length as the little finger. The nails are elongated, and acquire really the form of little claws in the *Ouistitis*. The posterior extremities offer the general character of the posterior extremities in the monkeys; the thumb of the hind hand is distant, and has a flat nail in the *Ouistitis*, while on the other fingers there are small claws.

NEUROLOGY. — The brain of the *Cebinæ* differs much in the various genera which are referred to this large division of *Quadrumana*. In the *Cebi* it is perfect, and approaches much to the brain of *man*, as may be seen in the drawing given by TIEDEMANN in his excellent work. But, according to the observations of I. GEOFFROY ST. HILAIRE and of myself*, there are no circonvolutions on the proportionally very large brain of the *Ouistitis*, and there are but few in the *Saimiri*, in which the anterior lobes are not so much developed as in the *Cebi*. To these statements LEURET† made some objections, which have been sufficiently refuted by I. GEOFFROY ST. HILLAIRE.

MYOLOGY.—As respects the muscles, those of the tail only deserve a special notice. They are very strong, especially the *flexores*. By them the *Ateles*, if it is wounded to death, remains a long time, hanging on his tail. For the same cause its tail is always inflected when in the state of rest. The *Cebi* sustain their body on it, if they are forced to go on their hinder legs. The other muscles seem not to differ from those of the monkeys of the Old World. The general description of these may be applied to them.

SPLANCHNOLOGY.— The soft parts afford no material for such interesting observations as those of the monkeys of the Old World. The larynx wants in general the pouches, which I have described before. There are but two exceptions yet known, one in the *Marikina* (*Hapale rosalia*), in which CUVIER and CARUS state that they have found a laryngeal pouch, which, according to CUVIER, communicates with the larynx between the thyroid and cricoid cartilages. The second exception is the *Ateles paniscus*, in which there is a membranous expansion behind the cricoid cartilage. The hyoid bone of *Ateles* has the form proper to the monkeys of the Old World. In *Cebus* it approaches more to the form of *man*, by a more truncated pyramidal and a less convex or scutiform base.

The disposition of the laryngeal apparatus in the genus *Mycetes* deserves a more accurate notice. It is distinguished, as may be seen in *fig*. 134, by a peculiar tympaniform dilatation of the base of the hyoid bone, by which a repercussion of the exhaled air seems to be produced. A great resonance, effected by the elasticity of the parietes of this bony cavity, must be the result of this repercussion, by which the terrible howlings of these animals are produced.

Upon the other soft parts of the *Cebinæ* there is nothing very particular to say. I mention only the structure of the stomach in *Ateles* and *Mycetes*, in which, according to the observations of CUVIER and of Prince MAXIMILIAN, there is some tendency to the sacculated form of the stomach in the *Semnopitheci*. This peculiarity confirms all that I have said before about the analogy between *Ateles* and *Semnopithecus*. In the organs of generation the length of the clitoris is worth notice, particularly in *Ateles* and *Cebus*. According to the observations of LEUCKART * it has an

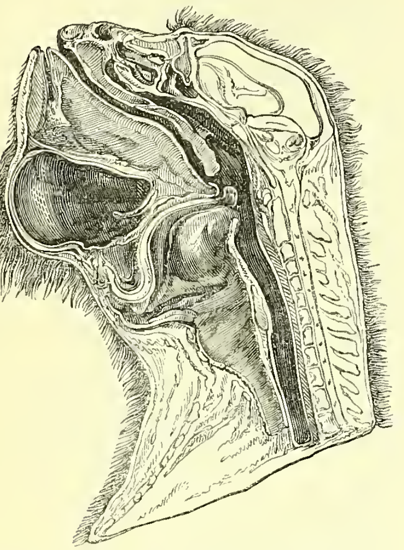
* Comptes Rendus, t. xvi. n. 23, 1843, 12 Juin, p. 1236, and Description des Mammifères Nouveaux, etc., in Archives du Museum, tom. ii. liv. 4., Paris, 1841, p. 515.

† Comptes Rendus, tom. xvi. n. 24. p. 1372. LEUCKART agrees with these observations of I. GEOFFROY ST. HILAIRE, saying that he found scarcely any convolutions in the brain of *Hapale rosalia* and *jacchus*. Recently I. GEOFFROY ST. HILAIRE has showed to the French Academy two brains of *Ouistitis*, and has invited the members to verify the three statements which he published, viz., "l'existence de chaque côté d'un sillon profond transversal entre le lobe cérébral antérieur et le lobe moyen ; celle de quelques sillons linéaires et superficiels correspondant au trajet des vaisseaux, et l'état lisse de la presque totalité de la surface des hemisphères." — Comptes Rendus, n. 714, Août, 1843, p. 280.

* F. S. Leuckart, Zoologische Bruchstucke : Stuttgart, 1841, ii. p. 61.

os clitoridis, which grows larger at its anterior extremity. Rudolphi seems to have been misled by it, in his description of a presumed hermaphroditical monkey. It is very probable that he did not examine an hermaphrodite, but a female *Cebus capucinus*.*

Fig. 134.



Vertical section of the hyoid bone and larynx of Mycetes seniculus. (*After Sandifort.*)

About the embyro-genesis of the *Cebinæ* Rudolphi published some interesting notices. He observed in the *Ouistitis* that the omphaloid vesicle persists till the last period of gestation, and that there are in *Hapale*, *Mycetes*, and *Cebus* two umbilical veins, which unite near the liver.

As an appendix to all these anatomical observations about the *Cebinæ*, I join the results of the dissection of *Nochthora trivirgata*, which I made in the month of July, 1843, in the Zoological Society of London. The stomach has the transversely oblong form proper to the monkeys in general, and not the round form of the *Stenops*; consequently the cœcal sac is not so ample as in *Stenops*. The cœcum terminates in a more elongated cœcal point than in *Stenops*. It wants cells, as in the greater part of the American monkeys. In the encephalon the hemispheres are larger in their anterior lobes; they cover almost the whole cerebellum; the *fossa* Sylvii is transverse, and very deep; the mesial lobes are very distinct; the asymetry between the two hemispheres is not so distinct as in *Stenops*, by all which characters the brain of the *Nochthora trivirgata* approaches to the monkeys, and differs from *Stenops*. The laryngeal apparatus has a great deal of analogy with that of *man;* the thyroid cartilage is large and prominent, and has almost the same form as in *man*. The *epiglottis* is much developed, particularly at its base. The arytenoid cartilages are much elevated. The *rima glottidis* is wide. The tongue differs from the same organ in *Stenops*, in which it is sustained by a triangular and flat cartilage. In the *Nochthora*, on the contrary, it has the general structure of the tongue of the monkeys, being long and narrow, with isolated *papillæ*. The heart has an oblong form. The first ramifications of the *arcus aortæ* are similar to those of man. The right lung is divided into four, the left into two lobes.

* Rudolphi, ueber eine seltene Art. des Hermaphroditismus bei einem Affe (*Simia capucina*) in Abhandl d. Konigl. Akad. d. Wissensch. in Berlin, in J. 1816—1817; Berlin, 1819, 4to. Physik. Classe, p. 119.

II. Lemurinæ. *Prosimiæ*.

The second large family of Quadrumana is formed by the *Lemurinæ*. They have the general aspect of the American monkeys, but their muzzle is lengthened and pointed, and in the hind feet the first toe is the only one armed with a crooked subulated nail, while the other nails are flat. The four thumbs are opposable; the teeth differ very much in the different genera, but the molars offer in general the pointed and alternating tubercles proper to the *Insectivora*.

1. *First Genus. Otolicnus* Illig. *Galago.*

The teeth of *Otolicnus* are as follows, viz. incisors, $\frac{4}{4}$; canines, $\frac{1-1}{1-1}$; molars, $\frac{6-6}{6-6}=36$. The inferior incisors are very narrow and compressed; they resemble much the teeth of a fine comb, and are entirely united together. The tarsus is very long, by which the hinder extremities acquire a disproportionate size, and produce a jumping motion. Their tail is very bushy; their ears large and membranous; their eyes very large, and announce their nocturnal habits. Africa.

Spec. — *Otolicnus Senegalensis*, *O. Madagascariensis*.

2. *Second Genus. Tarsius. Tarsier.*

Incisors, $\frac{4}{2}$; canines, $\frac{1-1}{1-1}$; molars, $\frac{6-6}{6-6}=34$. Has the remarkably long hind legs, the large ears and eyes of the preceding genus; but the interval between their true molars and their incisors is filled up with short acuminated teeth, of which it is difficult to say if they are canine or molar, and the superior middle incisors are very long, and resemble canine teeth. The muzzle is very short. They inhabit the Mollucca islands, and are nocturnal animals, feeding upon insects.

Spec.—*Tarsius spectrum*.

Third Genus. Stenops Illiger. *Loris. Singe paresseux*, Fr. *Spookdier*, Dutch.

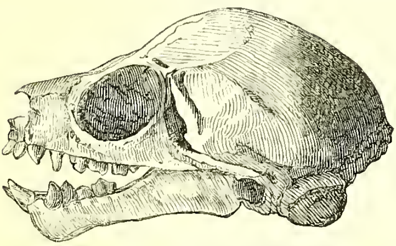
The teeth as in the *Lemurinæ* in general, but the external incisors of the upper jaw are very

often wanting. The first molar of the lower jaw on each side is so much acuminated and incurved that it resembles a canine. The muzzle is short and triangular; the ears small; large nyctalope eyes, close to each other; no tail, or a short one, and a long narrow tongue. They feed upon insects. Their habits are nocturnal, and their movements very slow. They inhabit Eastern Asia.

Spec. — *Stenops tardigradus*, *S. gracilis*, *S. javanicus*.

To these ought to be added the *Stenops potto* Bosman, coming from the coast of Guinea. It has a short tail and a short index. In a skull of a young *Stenops potto*, from the Museum at Leyden (*fig.* 135), the distance

Fig. 135.



Skull of Stenops potto. (*Original, Mus. Leyden.*)

between the two orbits is much larger than in *Stenops javanicus*, *tardigradus* and *gracilis*. It is the narrowest in *Stenops gracilis*, broader in *Stenops javanicus*, still broader in *S. tardigradus*, and the broadest in *S. potto*. In *S. potto* the circular boundary for the orbits is not so distinct as in other species.

Fourth Genus. Lichanotus Illiger. *Indri.*

The same form of teeth, but they have only two incisors in the lower jaw. This genus has but one species (*L. Indri*), distinguished by the want of the tail. Madagascar.

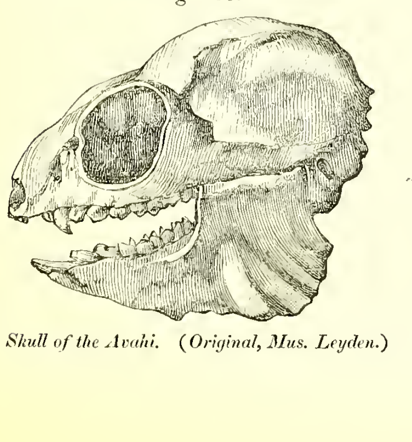
The dental formula is:

Incisors, $\frac{4}{2}$; canines, $\frac{2}{2}$; molars, $\frac{10}{10}$=30.

Fifth Genus. Semnocebus Lesson. *Avahi.*

The *Semnocebus* approaches very much to *Lichanotus*, from which it differs by the existence of a tail, and by the form of its skull. In a skull of the *Avahi*, Mus. Leyden (*fig.* 136),

Fig. 136.



Skull of the Avahi. (*Original, Mus. Leyden.*)

I observe a depression on the frontal surface, between the two orbits, which part is, on the contrary, convex in *Lichanotus*. The muzzle is not so much protruded as in *Lichanotus*, and more flat on its anterior part, formed by the intermaxillary bones. The teeth are the same in both. Madagascar.

Spec.—*Semnocebus laniger* or *Avahi.*

Sixth Genus. Cheirogaleus.

Among the unpublished drawings of Commerson, Geoffroy St. Hilaire discovered representations of certain Lemur-like animals, which he considers as constituting a distinct genus. The characters were at first very indistinct; but we are now acquainted with the external aspect, the skull, and the teeth of this genus. The dental formula is: incisors, $\frac{2-2}{6}$; canines, $\frac{1-1}{1-1}$; molars, $\frac{6-6}{5-5}$=36. The superior incisors are situated in two pairs, with a great interval between both. On each side of the upper jaw there is a large canine, with six molars, of which the two first have acuminated crowns, and seem to be spurious molars; the four posterior are tuberculated. In the lower jaw there are six long and narrow proclive incisors, of which the two exterior are the strongest; a vertical canine on each side; a spurious molar with acuminated crown, and five true tuberculated molars. In the form and the size of the skull, *Cheirogaleus* has some analogy with *Lemur*, particularly by a peculiar opening in the zygomatic bone. The muzzle however is not so prominent, and the interval between the orbits smaller. The form of the skull is intermediate between *Lemur* and *Stenops.*

Spec.—*Cheirogaleus* Commersonii.

Seventh Genus. Lemur. Maki, Fr. *Meer-kat,* Dutch.

Incisors, $\frac{4}{4}$; canines, $\frac{1-1}{1-1}$; molars, $\frac{6-6}{6-6}$ = 36.

The six inferior incisors are compressed and directed forwards; of the four superior vertical incisors, the two middle are distant from each other; the canine teeth are very acuminated; the molars acuminated and alternating in each jaw. The ear not much developed. The tail long, bushy, and highly ornamented. The muzzle is very prominent, lengthened, and pointed; for which reason the French call the Makis *Singes à museau de renard* They feed upon fruits, and inhabit chiefly Madagascar.

Spec. — *Lemur catta*, *L. macaco*, *L. ruber*, *L. mongos*, *L. albifrons*, *L. nigrifrons*, *L. rufus*, *L. albimanus*, *L. cinereus*.

The *Lemur murinus*, *Maki nain* ought to be separated from the other *Lemurs*. It seems a transition to *Otolicnus*.

Eighth Genus. Galeopithecus. Vliegende-kat, Dutch.

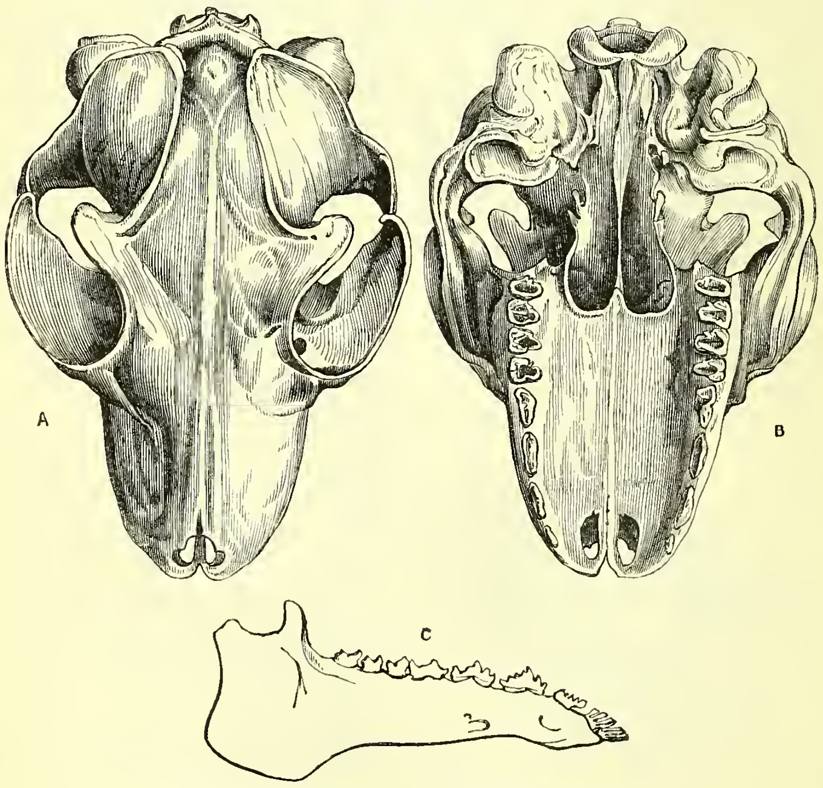
This genus has been considered by Cuvier to belong to the *Cheiroptera*, but Temminck and De Blainville have perfectly well de-

monstrated that it is not a *Vespertilio* but a *Lemur*, and that it forms in this way a transition from the *Lemurinæ* to the *Cheiroptera*. The author of the article CHEIROPTERA in this *Cyclopædia* has adopted the same views, and I agree with them, including the *Galeopithecus* in my present paper. The *Galeopithecus*, then, is a *Lemur*, with the extremities connected by a bat-like membrane, or, in other words, surrounded by a thin skin, which they support as the framework of the *umbrella* sustains its covering. By this singular structure, the animal while jumping is suspended in the air, yet without the power, as the Bats, of a continued flight. The fingers of the hands are not longer than those of the feet, and provided in both with long and sharp incurvated claws. They dwell upon trees in the Indian Archipelago, and feed upon insects, and, perhaps, little birds. They sleep, as the Bats, suspended by their hind legs, with their head downwards. According to the observations of WATERHOUSE, their dentition is as follows: incisors, $\frac{2-2}{4}$; canines, $\frac{0-0}{1-1}$; false molars, $\frac{2-2}{2-2}$; true molars, $\frac{4-4}{4-4}=34$. The form of these teeth is very strange. The anterior incisor of each side in the upper jaw is of a small size and compressed form, suddenly dilated above its insertion in the jaw, serrated at the edge, and presenting three or four nearly equal denticulations. The second incisor on either side resembles the first false molar in form, and, like that, has two fangs. The first false molar is compressed, of a triangular form, and has the anterior and posterior edges serrated. The second false molar is less compressed than the first, and divided into two nearly equal, acutely pointed, triangular cusps; the *apex* of the posterior cusp is directed inwards. The triangular grinding surface of each of the true molars consists of three pointed cusps. The molars of the lower jaw resemble those of the upper, excepting that the position of the three principal cusps is reverted. The false molars are compressed and resemble, in general, their opponents of the upper jaw. The tooth, which represents the canine, is comparatively small, compressed, and considerably expanded at the *apex*, where it is serrated, having five or six denticulations. The incisors are almost horizontal in their position, compressed, narrow at the base, and suddenly expanded immediately above the base; each incisor is deeply festooned or subdivided by incisions into slender *laminæ*. The incisors and false molars of the lower jaw are detached.

Spec.—*Galeopithecus variegatus.*

OSTEOLOGY.—The considerations upon the skeleton of the *Lemurinæ* ought to be con-

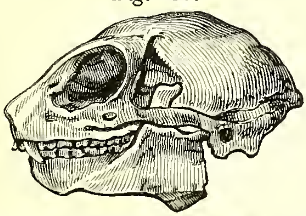
Fig. 137.



Skull of Galeopithecus variegatus. (*After Waterhouse.*)

nected with those upon the *Cebinæ*, in which I said that the form of the bony framework passes gradually and in a descending line into the form of the *Lemurinæ*, and by those into the form of the smaller *Carnivora* and *Insectivora*. The truth of this assertion will be proved by the examination of the skull. In all the skulls of the above-mentioned genera of *Lemurinæ*, the orbits are open posteriorly, and most so in the *Galeopithecus* (*fig.* 137), which we shall take as type, and in which there is a large distance between the orbital process of the frontal and of the zygomatic bone united together in *Tarsius*, *Lichanotus*, *Stenops*, *Otolicnus*, and *Lemur*, and forming there a boundary for the open orbit. In all the *Lemurinæ* there is a double frontal bone, with two nasal bones, which are universally very long, and protracted to the anterior part of the muzzle, principally in *Stenops*, in which they form a sort of tube with the intermaxillar bone. The facial suture of the intermaxillar bone is in general distinct. The lacrymal canal is situated not in the orbit, but on the facial surface of the superior maxillary bone; in *Cheirogaleus* (*fig.* 138) and *Lemur*, there is a regular oval

Fig. 138.



Skull of the Cheirogaleus Commersonii. (*Original, Mus. Leyden.*)

opening, in the zygomatic bone, similar to that, which I described in *Lagothrix*, *Mycetes*, and *Ateles*. In the glenoid cavity of the temporal bone there is a vertical ridge to prevent the backward dislocation of the lower jaw. The coronoid process of the lower jaw is very distinct, as in all the animals, in which the orbits are open posteriorly, and the chin is more depressed than in the *Monkeys* and *Cebinæ*.

In the vertebral column the cervical *vertebræ* are seven in number. The anterior vertical ridges of the transverse processes, in the posterior cervical vertebræ, are more developed than in the *Cebinæ*, and extended over a larger number of vertebræ. The spinal process of the epistrophæus has the quadrangular form with the posterior cutting edge of the *Carnivora*. In the dorsal vertebræ, the tendency to the form of the lower orders of Mammalia is still more distinct, firstly in their augmented number, which is in general 13, but increases to 15 or 16 in *Stenops*. The spinal processes offer the opposite direction which is proper to the inferior orders of Mammalia, excepting in *Stenops* and *Lichanotus*, in which they are all inclined backwards. The bodies of the dorsal vertebræ are in general all of the same size, and they do not augment, as in the higher order of monkeys of the Old World. In the lumbar vertebræ there is also an augmentation of number, which varies from 6—8 or 9. In *Lemur* the form and direction of the spinal lumbar processes have much analogy with those of the *Carnivora*, being incurvated and directed forwards. In *Stenops*, *Otolicnus*, and *Lichanotus*, they have a more quadrangular form. The styloid processes are much developed. The transverse processes are strong, quadrangular, and directed forwards, as in the *Carnivora*. The sacrum has the form of a large quadrangular bone, with sharp and straight edges, united by one, two, or three spurious vertebræ with the iliac bones. The form of the pelvis resembles that of the *Carnivora*. The iliac bones have two surfaces, an anterior or internal, slightly convex and narrow, a posterior or external, concave and broad. They unite together in a sharp, anterior edge, of which the anterior and inferior iliac tuberosity forms the anterior and inferior termination. The horizontal branches of the pubis are very distant, and make the pelvis pretty large. By this disposition and by the inclination of the pelvis, it resembles very much that of the *Carnivora*, and especially of the *Cercolcptes caudivolvulus*, which has so many other points of analogy with the *Lemurinæ*. The thorax is compressed, but the ribs are not very convex, as in most of the *Carnivora*. In the *Sternum* there is scarcely a manubrium, but its body is separated into as many long and narrow segments or *Sternebræ* as there are true ribs. In the scapula, the coracoid process is recurved and directed downwards, as in the Squirrels and other claviculated Mammalia. This is, as I have said before, a distinct manifestation of inferiority. In the humerus there is, in general, an aperture in the internal condyle for the passage of the brachial artery and the median nerve.

The fore-arm has a different disposition in the various genera. In most of them it is composed of the two ordinary bones, the *radius* and the *cubitus*, of which the radius is in general curved outwards, and the cubitus straight. But in the *Galeopithecus*, the transition to the form of the Bats appears in the disposition of the ulna, which is imperfect, not prolonged to the carpus, but terminated in a slender filiform extremity, which is united with the radius. In the hand, the quadrumanous type is visible in the thumb, which is separated from the other fingers, even in the *Galeopithecus*. But in no genus of the *Lemurinæ* is the form of the hand so peculiar as in *Stenops*. Its principal character consists in the shortness of the index, and in the proportional length of the thumb and of the fourth finger, which is the longest. The *carpus* is composed of the same number of ossicles as in the monkeys of the Old World; but as I have proved in another paper*, its connexion with the anti-

* W. Vrolik, Rech. d'Anat. Comp. sur le Genre Stenops d'Illiger, in N. Verhand. d. eerste classe van het Koninkl. Nederl. Instituut. Amsterdam, D. ix. 1843.

brachium is less firm, by which the hand acquires a great deal of mobility, and can be inclined, as I have often observed, not only outwards, but also backwards. With regard to the posterior extremities, the principal deviation is offered by the *Tarsius*, in which the fibula is but a slender filiform bone, not extended to the tarsus, but terminating on the third inferior part of the tibia, with which it is united. Consequently the tarsal articulation is only united with the tibia. A yet more striking peculiarity is exhibited in *Tarsius* and *Otolicnus* by the tarsus, in which the calcaneum and the scaphoid bone are two long styliform bones, contributing in that way to produce the enormous length of the posterior extremities. In the *Stenops* there is not so great a deviation from the ordinary form to be observed; but it is, however, of some interest, that the two *Malleoli* are very small, and that the astragalus has an oblique direction inwards. The results of this disposition, as I have proved more minutely in the said paper, are a greater mobility of the foot, a direction upwards of its internal edge, and a great interval between the thumb and the other digits.

Myology. — I can only mention the muscles of the *Stenops*, having had no opportunity to dissect the other genera of *Lemurinæ*. The *sterno-mastoideus* has a distinct clavicular fascicle, the existence of which is very interesting, while it is not found in some monkeys, nor in any of the mammalia which have no clavicles. In the *M. digastricus* there is but an indication of intermediate tendon; consequently the muscle is simplified, and passes into the form it has in the *Carnivora*, in which it is composed of a single fascicle. Another peculiarity in the muscular system of the *Stenops* is the existence of the *omo-hyoideus*, which is wanting in many large Mammalia, but exists in the monkeys, and as my dissection has proved in the *Dasyurus*, the *Ursus arctos*, the *Pteropus*, and the *Opossum*. This muscle is also one of the links connecting the genus *Stenops* with the *Quadrumana* on one, and with the *Carnivora* on the other side. The *latissimus dorsi* gives, in the same manner as in so many other climbing animals, a prolongation to the internal condyle of the humerus. The *pectoralis magnus* has the length and the strong disposition of fibres, proper to all the quadrupeds. As in them, the clavicular fascicle is not much developed. The disposition of the *biceps* and *brachialis internus* is interesting, because it proves that the genus *Stenops*, and probably the other *Lemurinæ*, form a transition from the *Quadrumana* to the *Carnivora insectivora*. In the same manner as in these, the *biceps* consists of but one fascicle, which arises from the superior edge of the articular cavity of the scapula, and is inserted into the radius, and the *brachialis internus* possesses but an external fascicle, which passes to the antibrachium, behind and under the *biceps*. It is very remarkable, that notwithstanding the want of the internal fascicle of the *biceps*, there is a *coraco-brachialis*. It is prolonged downwards to the internal condyle of the humerus; between it and the internal fascicle of the triceps passes the cubital portion of the vascular plexus. This is an exception to the rule, that the existence of a *coraco-brachialis* is connected with the existence of an internal fascicle of the *biceps*, and an additional proof that the genus *Stenops* forms a transition from the *Quadrumana* to the *Carnivora*. In the antibrachium the *pronatores* and *supinatores* are very strong. The *flexores* are the *radialis* and *ulnaris internus*, with the *palmaris longus*. The *extensores* are the *radialis externus longus et brevis*, with the *ulnaris externus* and the *extensores* of the fingers. For the flexion of the fingers, there is a rudimental *flexor superficialis*, which is wanting in the *Carnivora*, and which exists, on the contrary, in the *Quadrumana*.

Instead of the *abductor magnus* and *extensor brevis pollicis* there is but one muscle, formed by the union of both these muscles. I have shown already that this tendency to simplify is yet observed in the *Orang-œtan* and in the *Mandrill*, and more distinctly in the *Inui*. Besides this the thumb of the *Stenops* possesses a *flexor brevis*, an *abductor brevis*, and an *adductor pollicis*.

In the posterior extremities we observe, first, a very long and very strong *psoas*, composed of two portions, of which the internal is the strongest. They are united to the *iliacus internus* and attached to the small trochanter. The *sartorius* has an oblique direction, and is attached to the internal edge of the *tibia*. The *gracilis* is broad and attached lower to the *tibia*. The *rectus femoris*, the *cruralis*, *vastus externus* and *internus* have their usual disposition. There is no *pectinæus*, but there are three *adductores*. It is very remarkable that the *adductor magnus* forms no aponeurotic canal for the passage of the plexiform crural artery, but that this passes only on the superior margin of the *adductor magnus*, and penetrates in this manner into the popliteal cavity. I have stated the same disposition in the *Bradypus didactylus*, in which, and also in the *Stenops*, this deviation seems to be connected with the peculiar ramification proper to the vessels of the extremities, by which they are more preserved from compression, than in the animals, in which the crural artery forms but a single tube. On the posterior surface of the thigh there are a *semi-tendinosus*, *semi-membranosus* and *biceps*. The *semi-tendinosus* is united to the *gracilis*. The *semi-membranosus* has its own insertion. They descend very low and surround the *gastrocnemius*. The biceps terminates on the superior part of the tibia with a large muscular fascicle. The *glutæus maximus* has a large insertion on the thigh, and is inserted very much downwards. On the anterior crural surface there are a *tibialis anticus*, an *extensor magnus* and *brevis digitorum pedis*, and *extensor brevis hallucis*, which has a very oblique direction, and a *peronæus magnus* and *brevis*. As regards the *flexores*, I have only to mention the union of the *flexor magnus hallucis* with the *flexor mag-*

nus quatuor digitorum pedis, which are united in the same manner as in the monkeys. They both give tendons to the toes, of which each receives consequently two tendons. The plantar surface of the tendon of the *flexor magnus quatuor digitorum* give off four lumbrical muscles. Instead of a *flexor brevis* there are but small tendons, which bifurcate for the passage of the tendons of the *flexor magnus hallucis*, and *flexor magnus quatuor digitorum pedis*. The *tibialis posticus* is very strong. The small muscles of the posterior thumb or great toe are the *abductor*, the *flexor brevis*, and the *adductor*. Their strength is connected with the mobility and with the removed position of the posterior thumb, giving a great deal of agility to the *Stenops* in his climbing motions.

Neurology.—The encephalon of the *Lemurinæ* is only known by the dissection of the *Lemur mongos* and of the *Stenops javanicus* and *tardigradus*. Science is indebted for the first to Tiedemann, and for the two last to Schrœder van der Kolk and to myself. The encephalon of *Lemur mongos* seems superior to that of *Stenops*, by the larger development of the hemispheres, the greater breadth of the anterior lobes, the more numerous convolutions and deeper anfractuosities, but otherwise they offer the same type. I have minutely described the brain of the *Stenops tardigradus* in my paper on this animal, and I mentioned there the small development and the asymetry of the hemispheres (*fig*. 139), the triangular form of the anterior lobes, the few convolutions, the shallow anfractuosities, the scarcely indicated *fossa Sylvii*, the not prominent *pons Varolii*, the very thick cerebral peduncles (*crura cerebri*), the want of *corpora candicantia*, the short *corpus callosum*. In all these points the brain of the *Stenops* is inferior to that of the monkeys, from which *Stenops* differs also by more imperfect intellectual faculties.

Fig. 139.

Brain of Stenops tardigradus. (After W. Vrolik.)

For the organs of sense, I mention principally the interesting existence in the *Stenops*, of the *tapetum lucidum* in the eye, by which the animal acquires the faculty of reflection of the light, improperly called phosphorescence of the eyes. In general the sensibility of the eye to light is very exquisite. Therefore most *Lemurinæ* are nocturnal, and see very well in almost profound obscurity, as is proved by the observations of F. Cuvier, in the *Lemur murinus*. The ears of *Stenops* are very large; the concha deep, the *tragus* and *antitragus* elevated, and instead of *anthelix* there are two prominent and almost parallel cartilaginous plates. The same development of the ear is observed in the genus *Otolicnus*. This great development in a nyctalope animal is an interesting fact, principally by comparison with the *Cheiroptera*, in which the same disposition occurs. The tongue of the *Stenops* offers a strange structure in the existence of a cartilaginous plate, by which it is supported, and the anterior margin of which is denticulated.

Angeiology.—I only know some peculiarities about the heart and the vessels of the *Stenops*. It has a rounded and plane form; the right ventricule is scarcely longer than the left, and terminates in a rounded point. The right auricle is much larger than the left. The distribution of the trunks coming from the *arcus aortæ* is as in the plurality of Mammalia, viz. three trunks coming from the *a. innominata*, and a separate left subclavian artery. But the most interesting is the ulterior distribution of the arterial and venous vessels in the extremities. Sir A. Carlisle was the first to show, that they form plexuous ramifications, consisting of a large number of narrow cylindrical vessels anastomosing together. Eighteen years ago, I repeated the observations of this excellent anatomist on various animals, and confirmed their veracity against the objections of Oken and Gaimard; and recently I had again the opportunity to show, that these ramifications exist in three species of *Stenops*; that in the same manner as has been proved for the *Bradypi*, by Schrœder van der Kolk and Otto, they consist not only of arteries, but also of veins; and that, by dividing in branches, these ramifications become smaller and smaller, and composed of a less number of vessels (*fig*. 140).

Splanchnology.—The stomach has in *Stenops* a rounded, almost globular form, in which the *cardia* is near to the *pylorus*, and the cœcal sac much developed. Consequently the concave margin of the stomach is small, the convex, on the contrary, large; with these is connected the elongated spleen. This disposition of the stomach, and especially the

approximation of the *cardia* and *pylorus*, seem proper to all the *Lemurinæ*, and already presents its first appearance in some *Cebidæ*. The cœcum terminates in an elongated, conic point, which ought not to be confounded with the vermiform appendix of the cœcum in *man* and in the *apes*. The cœcum is very large, and the colon has also a great extension. The colon is in general larger in the *Lemurinæ* than in the *Simiæ*. It is said by CUVIER to want cells. In *Lemur murinus* it is short and ample. DUVERNOY and SCHRŒDER VAN DER KOLK describe alternating constrictions and expansions in the intestinal canal of *Stenops*, which, however, I did not find in the three *Loris* I had the opportunity of dissecting.

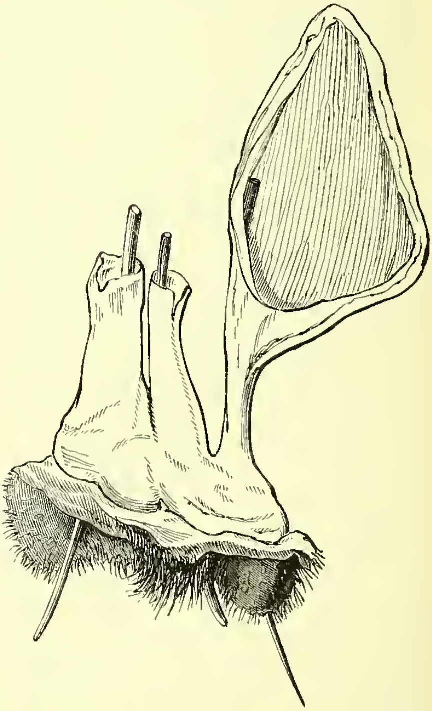
Fig. 140.

Superior limb of Stenops tardigradus. (*After W. Vrolik.*)

About the organs of voice and respiration I have, first, to mention the complete osseous disposition of the laryngeal cartilages; secondly, their small development; and thirdly, the bifurcated disposition of the *epiglottis.* All these points are proofs of imperfection, by which may also be explained the total want of voice in *Stenops*. The hyoid bone is different from the hyoid bone in the monkeys, and approaches to that of the inferior Mammalia. Its body is a transverse arch, slender, and united at the two extremities with the two pairs of horns. The anterior horns are composed of two distinct bones, of which the first is broad and flat, the second long and slender. The thyroid or posterior horns are broad and flat, and melting away with the basis of the bone, while the anterior have a free articulation. The hyoid with its horns has the form of a transversely inclined X, viz. $\asymp$.

In the organs of generation, the narrowness and convoluted disposition of the Fallopian tubes, the length of the vagina, and especially

Fig. 141.



Female external organs of generation of Stenop tardigradus. (*After W. Vrolik.*)

the perforated condition of the *clitoris*, merit our attention. The *clitoris* is very prominent, and through it passes the urethra. Consequently it has the structure of a penis, of which it is the representative in the female (*fig.* 141).

As appendix to my paper on the *Quadrumana* I think it necessary to mention the *Cheiromys psylodactylus* or *Aye-Aye* of Madagascar. This singular animal seems intermediate between the *Lemurinæ* and *Rodentia*. It has the teeth of the last, but all the other characters of the first. De Blainville has elucidated them in a learned paper, published a second time in his *Osteographie*, and he has proved, indeed, that by the general form of the skull, by the situation of the *foramen occipitale magnum*, and of the lacrymal opening, by the existence of an intermediate bone in the carpus, by the length of the calcaneum and scaphoid bone, the *Cheiromys* is indeed a Lemurine animal. But we want a more perfect acquaintance with its organization and with the form and number of its teeth in early age, before it will be possible to determine exactly, where this very rare animal ought to be placed.

To complete my anatomical description of the *Quadrumana* it will be necessary to mention the fossil specimens discovered recently in Europe, India, and Brazil. The European specimen consists in a lower jaw, discovered near Auch in a soil of tertiary formation. It seems to be of a *Cercopithecus*. The Indian specimen was found in tertiary formation of the mountainous district of the Himmalaya. It is a fragment of a lower jaw, having some analogy with the lower jaw of the Entellus. The third specimen is American, and consists in different bones of fossil Quadrumana, which seem to be of a *Cebus* much larger than the modern species.

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RADIAL AND ULNAR ARTERIES.

(*Artères radiale et ulnaire — Speichenpulsader und Ellenbogenpulsader.*) — The nomenclature of the different branches of the systemic circulation is based upon two principles. According to one of these, the distinction of appellation is grounded upon the tubes themselves; their different ramifications being designated by as many names, which usually more or less connote the ultimate destination of the vital fluid they contain. Where this method fails, another remains, which, though essentially arbitrary, is yet of the highest importance: a method which, in order to their stricter contemplation by the anatomist, and their more accurate recognition by the surgeon, isolates different lengths of one and the same tube, according to changes in its position and relations with respect to neighbouring parts.

The radial and ulnar arteries, whose anatomy is here to be considered, are included in the first of these categories; being the branches which result from the bifurcation of the artery for the upper extremity. Commencing in their ordinary distribution, opposite and anterior to the elbow joint, they

continue along the whole front of the forearm, each in tolerably close proximity to the bone whose name it bears.* The ulnar, by simply continuing this course, arrives at the hand, but the radial previously turns round the outer side of the wrist to reach the first metacarpal interval, which it perforates. Each now takes a curved course in the palm; a curve, whose convexity is forwards, whose situation — superficial or deep — follows that of the artery with which it is more immediately continuous, and which, completed by a branch or branches from its fellow, forms that from the ulnar the superficial, that from the radial the deep, palmar arch.

Since either of these arches has a share from both vessels, it might at first sight be supposed that we are here presented with a rare peculiarity in the uninterrupted artery traceable from the radial through its palmar arch to the ulnar, or vice versâ. But their apparent mutual continuity offers no difficulty to the exact nominal definition of each vessel and, obviously, the anastomosis differs from that common to all arteries only in degree: viz., in the greater freedom of communication which is the consequence of the larger size of the branches effecting it.

The brachial artery, inclining somewhat forwards in the lower part of its course, so as to gain the angle of flexion of the limb, lies at its termination on the brachialis anticus, where this muscle becoming tendinous, covers the coronoid process of the ulna previously to its insertion into the apex of the rough non-articular surface of this prominence. Here it divides.

The radial artery. Its relations. — The radial artery begins as the outer of the two divaricating branches, and ends as the deep palmar arch: in this course it offers three chief variations of regional anatomy, which will require a separate consideration. The first of these divisions may be regarded as terminating at the lower border of the radius, the second at the superior extremity of the first metacarpal space in the back of the hand, and the third at the point where, after breaking up into the radialis indicis, magna pollicis, and palmaris profunda vessels, the latter of these, lying deeply in the inner side of the palm, unites with the communicating branch from the ulnar artery.

(*a.*) *In the forearm*, the artery is directed at first downwards and externally, but afterwards more vertically, so as to exhibit a slight curve, whose convexity is upwards and outwards. It thus corresponds for a very short distance — say one third of an inch — to the coronoid process of the ulna, and lies on the brachialis anticus; but in the whole of the remainder of its length it is related to the anterior surface of the radius, and is situated on the muscles which immediately cover it. Crossing the inner surface of the tendon of the biceps as this sinks to its insertion, it by turns comes into contact with the cellular tissue on the supinator radii brevis, and lies upon the pronator radii teres, as this passes outwards to its insertion; then for a short distance the radial origin of the flexor sublimis digitorum sustains it, and next the flexor longus pollicis; by the passage of whose muscular fibres inwards to their tendon, it is left opposed to the pronator quadratus, but scarcely touching it from the depth at which this muscle is placed. To its outer side is the tendon of the biceps, and, at first distantly, afterwards more closely, the supinator radii longus, which maintains the relation throughout the remainder of this portion of the vessel: in this situation is also found the musculo-spiral nerve, which descends under cover of the inner border of the muscle, and passes away from the lower part of the artery towards the back of the wrist. To its inner side are successively, the pronator radii teres in about the upper half of the region, in the lower, the tendon of the flexor carpi radialis; and beneath this for a very short distance, that of the flexor longus pollicis. The coverings of the artery are merely the integuments and fascia of the forearm, so that in the whole of its length it is comparatively superficial: and the ordinary cellular tissue surrounds the vessel, while two venæ comites accompany its course.

It may considerably facilitate finding the artery in the living subject, to bear in mind the superficial indices of its course: and from what has been already stated it may be gathered, that in the upper half of this region the vessel is situated in a triangular hollow, whose base is the brachialis anticus in the lower part of the arm, whose outer side is the supinator longus, and whose inner side is the pronator teres. In the lower portion it occupies a linear and comparatively shallow depression, between two tendons whose margins the fingers readily recognise through the skin, viz. that of the supinator longus externally, the flexor carpi radialis internally. A line, therefore, from the inner border of the biceps tendon, to the inferior apex of the triangle, indicates with tolerable accuracy the first subdivision of its course; while another from this point, parallel and equidistant to the two tendons above named, marks it in the remainder of the forearm.

(*b.*) *In the wrist.* — This part of the artery is considerably shorter than the preceding, being scarcely one fifth of its length: its direction is downwards and outwards from the front of the forearm to the back and lower part of the wrist. In this course, the vessel lies on the external lateral ligament of the wrist joint, and at its termination on the posterior ligament of the same articulation; and corresponds to the scaphoid and trapezium bones which are beneath these. It is covered by skin and fascia, and at first situated at some distance from the surface, becomes towards its termination considerably more superficial. In its course it is crossed obliquely

* It will be borne in mind, that here, as in all descriptions of this part, the forearm is supposed to be supine, and hanging vertically by the side of the trunk.

by three tendons: in the first instance by two of these placed closely side by side, the extensores ossis metacarpi and primi internodii pollicis; but by the third, the extensor secundi internodii, only just before the artery enters the palm: so that between these two crossings, the vessel runs obliquely downward in the bottom of a groove, which is bounded on each side by these tendons, and whose depth is greatly increased by the action of the muscles with which they are continuous. It finally leaves the back of the hand, by passing between the processes of origin of the abductor indicis.

(*c*.) *In the palm.* — The vessel having perforated the metacarpal space, is situated very deeply in the palm of the hand, beneath the flexor brevis pollicis and the different structures superficial to this muscle; namely, the tendons of the flexores sublimis and profundus digitorum, with the lumbricales muscles, the branches of the median nerve, and, above these, the palmar fascia and integuments. Immediately giving off its magna pollicis and radialis indicis branches, it now crosses the palm as the *deep palmar arch*, or "palmaris profunda," which, slightly convex forwards, lies on the proximal extremities of the metacarpal bones, and on the interossei muscles between them; being directed at right angles to them towards the inner side of the hand, and joined in the fourth metacarpal space by the communicating branch of the ulnar, which completes the arterial circle. This latter part is of course uncovered by flexor brevis pollicis, and, just at its junction with the communicans ulnæ, it might almost be considered as covered by the flexor brevis minimi digiti.

Branches of the radial artery. — Amid very numerous ramifications, the following are those whose constancy and size require a separate mention.

(1.) *Arteria radialis recurrens.* — This large branch is given off from the outer side of the radial trunk almost immediately upon its origin from the brachial artery, and whilst it is contained in the triangular hollow before referred to. It passes at first downwards, then outwards, and finally upwards; lying on the supinator brevis and brachialis anticus successively; and then occupying the groove between the biceps and supinator radii longus muscles, but overlapped by the latter, it terminates in the arm by anastomosing with the superior profunda, which descends to meet it after passing beneath the outer head of the triceps. It has thus a curved course, the convexity of which is directed downwards towards the wrist. Its branches are very numerous, and chiefly supply the muscles with which it is in contact, inosculating with the vessels which they derive from other sources, and with the superior profunda as aforesaid.

(2.) *Arteria superficialis volæ*, which usually comes off from the artery just as it leaves the lower border of the radius to turn around the wrist; and, directed almost vertically downwards, proceeds over the annular ligament and immediately beneath the integuments, until it arrives at the muscles of the thenar eminence; amongst or upon which it passes, crossing them at an oblique angle, to join the termination of the palmar artery, or, in other words, to complete the superficial palmar arch. Liable to very considerable though unimportant deviations in its exact position, perhaps one of the most constant is that where the abductor pollicis lies over the vessel, itself placed upon the flexor brevis and opponens muscles. Its varieties in point of size are chiefly connected with the relative proportions of the other arteries, and are deferred to them; but it is usually a very small branch, and, quite as frequently as not, ends in these muscles without any direct junction with the superficial palmar arch.

(3.) *Arteria anterior carpi radialis.* — This is ordinarily a minute branch which comes off from the radial, either very close to the preceding, or a little above it. It runs directly inwards in contact with the anterior ligament of the wrist joint, or on the radius at a level just above this; to join with a similar branch from the ulnar on the opposite side of the wrist, and with the terminations of the anterior interosseous artery. It supplies the carpal bones and the articulation.

(4.) The *arteria dorsalis carpi radialis*, or posterior carpal branch, is considerably larger than the preceding, and is given off from the radial at a lower level, generally while the artery lies in the deep groove formed by the tendons of the extensors of the thumb. Its course is, like that of the anterior carpal, directly inwards beneath the tendons of the different fingers; and like it, at about the middle of the wrist, it terminates by uniting with a similar branch from the ulnar artery, and with the terminal ramifications of the interosseous vessels. Its size and arched shape are usually much more distinct than those of the anterior carpal vessels.

Other small branches are given off from the radial immediately previous to its entering the palm. Thus an *arteria dorsalis pollicis* is usually present, and divides, after a short course, into a branch for each side of the thumb; and there generally exists a similar twig for the radial side of the index finger, either as a separate branch from the radial artery, or from the ulnar division of the bifurcation just mentioned. A larger branch runs along the interosseous muscle in the second metacarpal space, to divide at its anterior extremity into branches for the opposed sides of the index and middle fingers. The vessels occupying the third and fourth spaces, with the same ultimate distribution, rarely arise from the radial; more usually they come from the posterior carpal arch, and sometimes from the previous metacarpal vessel, or from a similar ulnar branch lying in the fourth space. All these metacarpal branches unite, at the superior extremity of the interosseous space, with the deep arch by means of its posterior perforating branches; and at its inferior termination, with the digital branches

from the more superficial arch of the ulnar vessel. Their distribution to the fingers corresponds to that of the arteria dorsalis pollicis.

The *arteria magna seu princeps pollicis* is the first branch given off from the radial in the palm, and, as its name intimates, it is usually of considerable size. From the point of its origin it runs downwards beneath the flexor brevis pollicis and tendon of the flexor longus, lying on the metacarpal bone of the thumb, until near the metacarpo-phalangeal joint; where it divides into two branches, one of which occupies each border of the phalanges, and joins that opposite in the ordinary manner beneath the sentient cushion which forms the extremity of the thumb.

The arteria radialis indicis — also given off beneath the flexor brevis pollicis, runs yet more vertically downwards than the preceding, beneath that muscle and the adductor pollicis, and on the abductor indicis or first dorsal interosseous muscle, to become superficial at their lower borders. Here it gives off a tolerably large communicating branch to the superficial palmar arch of the ulnar artery, and from this point it passes along the radial side of the second metacarpal bone and index finger to its extremity, having a distribution in all respects like that of the digital branches of the palmar arch; its description is deferred to them.

From the arch itself are given off few branches of any size. Those which proceed downwards, lying on the palmar interossei, are three in number, one for each space, and anteriorly they end by inosculating with the digital branches from the ulnar, like the small twigs already referred to as occupying the same interosseous position on the dorsum of the hand. They have been named "anterior interosseous" branches. The remaining branches of the radial are *the posterior perforating*, three twigs which perforate the superior extremity of the same metacarpal spaces, to anastomose on the back of the hand with the posterior carpal and metacarpal branches.

The ulnar artery. — The remaining terminal branch of the brachial is usually much larger than the preceding, with which it is also contrasted by the more linear direction of its course, and by its situation in the different regions through which it passes; since it occupies the front of the limb from its commencement to its termination, and is placed less superficially in the forearm than in the hand.

Its relations in the forearm. — In this part of its course its direction is nearly straight, but with a slight convexity inwards, and it corresponds to the ulna in its whole length. At first lying on the brachialis anticus, by passing downwards and rather inwards, it next comes into contact with the flexor profundus digitorum which covers the bone; and it continues to lie on it to near the annular ligament. Superficial to the vessel are the skin and fascia of the forearm, together with the first layer of the muscles which occupy this situation, or the flexors which proceed from the inner condyle; viz., the pronator radii teres, flexor carpi radialis, palmaris longus, and flexor carpi ulnaris, successively. It is overlapped by the outer head and border of the latter muscle during about two-thirds of the forearm, being only uncovered where it becomes tendinous; in this lower part the artery lies external to this tendon, situated between it and the two inner tendons of the flexor sublimis; structures which would form a very easy guide to its locality during life. Although thus uncovered, the artery is by no means so superficial as was the case with the radial in the same stage; having in front of it fasciæ of great strength, and being placed in a deep depression, from the coming forward of the tendon of the ulnar flexor to its insertion in the pisiform bone.

The median nerve, which lay to its inner side on the brachialis anticus, crosses the ulnar artery very soon after the origin of the latter, the point of decussation exactly corresponding to the coronoid origin of the pronator radii teres, which slip of muscle lying over the vessel, separates the two structures. The ulnar nerve at its inner side above, where it enters the forearm between the condyle and olecranon, is in close contact with it in the lower half of this region, placed somewhat superficially and to its inner side. The ordinary venæ comites accompany the vessel.

In the hand.—In this latter part of its course the artery passes over the annular ligament of the wrist, internal both to the pisiform bone and the muscles of the hypothenar eminence; and next, as the superficial palmar arch, it passes transversely through this part of the hand, crossing superficially to the flexor tendons and the branches of the median nerve, until it arrives at the point to which we conducted the superficialis volæ, and the communicating branch sent upwards from the radialis indicis; a point nearly at the inner border of the prominent ball of the thumb. Though placed above the tendons and nerves the artery, however, is far from subcutaneous in any part of its progress; for while on the annular ligament, fibres from the insertion of the flexor carpi ulnaris into the pisiform bone pass outwards over its surface to join that structure external to the vessel lying on it; a little further downwards, the palmaris brevis, where present, is also directed inwards in front of it; and during the remainder of its length, the strong palmar fascia effectually shields it from immediate pressure. The vertical part of the vessel is accompanied by the ulnar nerve, which maintains the relation it had in the lower part of the forearm, and, inferiorly, divides into its digital branches. The arch, like that of the radial artery, previously described, is convex downwards, concave upwards; but it is obvious that its situation is considerably inferior to it, as well as much more superficial. A transverse line across either the middle of the hand or the centre of the metacarpus would tolerably indicate its position, or one continued across

the palm from the forcibly extended thumb might be taken as a more accurate guide to this part of the vessel.

Branches of the ulnar artery.—The first branches of the vessel are two, which usually come off by a common trunk, but are nearly as often separate at their origin. They are called the *arteriæ recurrentes ulnares anterior et posterior*, being so named from their taking a recurved course upwards into the arm; the former in the front of the internal condyle of the humerus, and the latter between it and the olecranon process of the ulna. The anterior recurrent passes upwards from beneath the flexor muscles which cover the artery where it rises, lying on the brachialis anticus, and corresponding to the elbow joint which it partially supplies; its superior termination inosculates with the lowest or anastomotic branch of the brachial. The posterior recurrent, having at first similar relations, passes more inwards so as to reach the above interval, being situated beneath the flexor carpi ulnaris, and meeting the ulnar nerve descending from the arm between the two heads of this muscle. Here it breaks up, anastomosing freely with the inferior profunda which has hitherto accompanied the nerve, uniting also by small branches with twigs sent downwards from the superior profunda in the substance of the triceps, and giving many branches to the articulation and the neighbouring muscles.

The next considerable branch is the *arteria interossea*, which diverges from the trunk of the vessel a little below the coronoid process, and whilst it is covered by the flexor muscles. Directed downwards from its origin, after a course of about an inch in length, it reaches the interosseous membrane in the upper part of the interval between the flexor longus pollicis and the flexor profundus digitorum, and here it bifurcates into two branches. One of these, the anterior interosseous, continues on the front of this membrane, lying deeply in the interval between the two muscles and concealed by them, until, arriving at the pronator quadratus which lies transversely across the lower extremities of the radius and ulna, it passes under this muscle. At its inferior border it reappears, though much diminished in size, and now situated on the anterior ligament of the wrist, it divides into many small branches, which supply the articulation and anastomose with the anterior carpal twigs from the radial and ulnar vessels. In this course, the branch now described supplies the muscle on each side of it, and usually it gives off one or two small branches which perforate the interosseous membrane beneath it in their passage backwards to the posterior region of the forearm. One of these, by far the largest and the most constant, is frequently named as "the posterior branch of the anterior interosseous;" and it escapes to the back of the forearm, through an aperture which exists in the interosseous membrane, near its inferior border, and about an inch and a half above the radio-ulnar articulation.

The posterior interosseous, the remaining division of the artery, leaves the front of the limb by passing between the radius and ulna above the superior border of the interosseous membrane, and next becomes visible in the back of the forearm, between the inferior border of the supinator brevis and the extensor ossis metacarpi pollicis. In the remainder of its extent it lies on the muscles which arise from the posterior surface of this membrane, and beneath the more superficial layer of extensors and supinators, until it arrives at the wrist. Here, lying on the posterior ligament of the joint, it breaks up into its terminal ramifications, which inosculate freely with the posterior carpal arteries of the radial and ulnar, and with the perforating branch of the anterior interosseous division.

While this vessel is passing between the two bones above the ligament, it gives off the recurrent interosseous branch, which, usually of considerable size, perforates the lower part of the supinator radii brevis to reach the back of the forearm. Subsequently it is directed upwards, lying on this muscle, and beneath the anconeus, until it attains the lower part of the arm, where it terminates by anastomosing with a large branch or branches which proceed from the superior profunda, as it turns round the humerus, and in the substance of the outer head of the triceps. It supplies the muscles between which it is situated, and sends a branch to the articulation of the elbow-joint.

A very constant branch, though usually only of small size, is the twig from the ulnar artery which accompanies the median nerve, continuing along it through the forearm until gradually lost from increasing minuteness. It is the basis of an important variety which will be mentioned hereafter.

Low down in the forearm, the ulnar artery gives off a branch which runs along the ulnar side of the metacarpus, and supplies this side of the little finger with a dorsal twig. Accompanied by a branch of the ulnar nerve, it turns backwards from the vessel just above the inferior extremity of the ulna, beneath the flexor carpi ulnaris tendon; and reaching the inner side of the wrist, continues in a direct line to its termination. It anastomoses with the posterior carpal arch, and, on the metacarpus, with the palmar arch of the ulnar artery.

The remaining branches of the ulnar in the forearm are two, the *arteriæ carpi ulnares anterior et posterior*, which occupy a position closely resembling that of the similar branches from the radial artery on the opposite side of the limb. Each runs transversely outwards on its respective surface of the wrist joint, and unites with the radial branch, and from this union, (which, in the case of the posterior vessels, is a "carpal arch" in size and regularity of arrangement) branches perforate the ligaments to supply the articulations and bones of the carpus. In addition to the

opposite vessel, the anterior inosculates with the termination of the anterior interosseous and with small branches sent upwards from the superficial and deep palmar arches: while the arch formed by the posterior joins the posterior interosseous, and the dorsal branch of the anterior interosseous; and gives off a small branch which occupies each of the two ulnar metacarpal spaces on the back of the hand.

The *communicans ulnæ* is a branch of large size, which passes away from the posterior surface of the ulnar vessel at about the lower border of the annular ligament, and disappears by sinking between the abductor and opponens minimi digiti, to join, deeply in the palm, with the ulnar extremity of the palmaris profunda or palmar arch of the radial, to which it usually approximates in size. It gives small branches to the muscles while passing between them.

In the palm of the hand, the *digital* arteries are the only branches of the vessel which attain any size: there are four of these, the first supplying the ulnar side of the little finger, and the remaining three corresponding each to the opposed sides of two fingers: the most external being between the middle one and the index. They occupy a situation superficial to the nerves and tendons, and continue forwards, each as a single branch, until they reach to the clefts of the fingers; lying in intervals between the commencing sheaths of the tendons, and limited in front by the transverse ligament of the fingers, and behind by the strong ligament on the heads of the metacarpal bones. In this space lies also the similar digital branch of the median nerve, but beneath the artery, and at its inferior termination, each bifurcates into branches for the neighbouring side of the fingers which bound the cleft. Here the vessels are crossed by the nerves, and in the remainder of their length, are situated along the border of the finger, to its termination, the nerve being anterior. At the extremity of the finger, the branch of each side gives off a twig to the under surface of the nail, and the remainder immediately uniting in an arch with the similar branch of the opposite side, breaks up into a network, whose meshes thus form a highly vascular subtratum to the sensitive papillary surface which especially occupies this part. In its course along the finger, beside many smaller branches, each digital artery gives off a transverse branch just above the several phalangeal articulations; which, by joining with its fellow, forms an arch whence proceed the smaller vessels to the joint.

Varieties of the radial and ulnar arteries. — The size of these vessels, together with the comparative exposure to mechanical injury which their situation involves, renders an exact knowledge of their distribution absolutely essential to the surgery of the upper extremity; and the same causes also require that the more important varieties, which constitute so large a per centage of their actual numbers, should at least experience some consideration. In sketching out a few of these it is impossible to avoid acknowledging great obligations to Mr. Quain's recent work, "The Anatomy of the Arteries," in which the number of subjects, which serve as the groundwork of the estimates, the evident care with which they have been examined, and the beauty of the illustrations, leave little to be wished for.

Varieties of origin. — Rarely does either of the two vessels arise from the brachial at a point lower than the ordinary situation opposite the coronoid process of the ulna: a higher division of this artery, or as it is called, a "high origin" of one of these its branches, is, on the contrary, by no means an uncommon occurrence. It is worthy of notice, that in the majority of these cases, there is no lateral correspondence of the variety, — in the opposite limb the distribution is the usual one.

The most frequent of the two is *the high origin of the radial*, which may come off from the axillary, or from the brachial artery in any part of its course. In this case, the remaining trunk, although directly continuous with the ulnar artery, and lacking the usual means of distinction from it, bears yet the name of brachial, since it generally possesses the ordinary relations and distribution of the latter vessel. Under these circumstances, the radial passes down the arm from the place where it is given off, generally lying rather close to the brachial, and on its outer side, until it reaches the forearm; subsequently it preserves its usual arrangement and termination. But though, for the most part, its course is thus only altered by the possession of an additional portion in the upper arm, this irregularity is sometimes associated with another which concerns its course, viz., a position of the artery superficial to the fascia; and here it would often have a close juxtaposition to the median basilic vein at the bend of the elbow, which carelessness in venæsection might render dangerous or even fatal. A similar deviation may obtain in the remainder of its course, placing it superficially to the supinator radii longus, instead of beneath its overlapping inner border; or causing it to cross over the extensor tendons at the wrist instead of under them. The latter variety is frequently associated with another alteration in the course of the vessel, which, after giving off the superficialis volæ at a point much higher than usual, immediately turns round the outer border of the forearm, so as to leave this small branch alone occupying its ordinary position at the wrist. Other deviations are comparatively rare: — thus occasionally the vessel enters the palm in the second instead of the first interosseous space.

Variations in its *distribution* appear chiefly dependent on its relative size. If smaller than usual, a kind of enlarged communicans ulnæ reinforces its deep palmar arch, or gives off its radialis indicis and magna pollicis branches: or the compensative stream may arrive by another channel, viz., a dilated anterior interosseous to join the artery as it turns round the wrist; or by a large posterior branch of

the same vessel which meets it just before entering the metacarpal interspace. Where, as is by no means infrequent, the radial is larger than ordinary, its increased size is principally expended in supplying, through a large superficialis volæ artery*, one or more of the outer digital branches which usually come from the superficial palmar arch: or, by means of a dorsal metacarpal of unusual magnitude, digital branches to the opposed sides of the index and middle fingers.

The *high origin of the ulnar* is contrasted with that of the radial in another respect beside that of its lesser frequency, since it is almost always conjoined with an important difference in the situation of the vessel in the forearm, which lies superficial to the flexors ordinarily covering it, and immediately beneath the fascia: — sometimes it is even sub-cutaneous. Its *course* is also somewhat affected by this origin, the vessel approaching the inner side of the forearm at a higher point than usual: in other cases, however, it possesses almost a median position during the greater part of this region, and only turns inwards to its ordinary distribution near the wrist.

In *size*, the ulnar artery is more frequently diminished than increased by variations. The decrease is compensated sometimes by a radial vessel supplying one or more of its digital branches or contributing to its palmar arch: at others, its long branch which accompanies the median nerve is enlarged to a vessel of considerable size, which similarly assists it; while, in a few instances, the dilated anterior interosseous has an analogous termination.

The origin of the interosseous artery is subject to some variation, being liable to occur as a divarication from the radial or brachial, or though rarely — from the axillary: its enlargement aids a deficient radial or ulnar vessel, just as its diminutive size is supplied by them.

The branch with the median nerve enlarged to a "median" artery, has been already mentioned; it passes under the annular ligament as it enters the hand, and may reinforce the deficient radial or ulnar; but most frequently the latter of the two, by joining the superficial palmar arch.

Finally, as to the varieties in the hand, the mode in which a diminished superficial palmar arch is obviated, has already been described; and an unusually small deep arch is compensated by the ulnar communicating, which is generally little inferior in size to the radial contribution. For individually smaller digital branches are substituted enlarged dorsal metacarpal; and in the case of the magna pollicis the superficial palmar arch, the superficialis volæ, or the median artery, may either of them make up the deficiency.

It may be desirable to attempt a generalization of these special variations; in order to this, let us return for a moment to the ordinary anatomy of the vessels of the forearm and hand considering them as a whole. Such a view assisted somewhat, it must be confessed, by our knowledge of these varieties, would discover in the forearm five longitudinal trunks, all possessing some feature, whether of size, length, or constancy, which especially recommends them to our notice. They are the radial, ulnar, and anterior interosseous vessels, together with the posterior branch of this latter, and the branch with the median nerve. The anastomosis and distribution of the extremities of most of these, forms around the wrist an arterial circle which is much more pronounced posteriorly.* In the hand, two arches which are continuations of the larger vessels occupy its surface of flexion, at different heights and depths; defended from the pressure inseparable from prehension by a strong fascia, whose protective effect is aided during flexion by a tightening muscle. They join by anastomosis with the extremities of the longitudinal vessels, or the imperfect anterior carpal arch. Three branches run lengthwise in most of the metacarpal interspaces; one on the dorsum from the posterior part of the carpal circlet, two at different depths in the palm from these arches; the dorsal and deeper palmar uniting at the superior extremities of those intervals, and all three inosculating at their inferior terminations near the clefts of the fingers.

All the varieties above mentioned would be referrible to the increased development either of one of these longitudinal branches, or of some portion of this complete and large anastomosis. The several varieties are, in fact, an exaggeration by turns of a different vessel; which in its course towards distribution may return its contents to the ordinary channel by any one of these series of inosculations; whether it be the superficial or deep arch, the posterior carpal arch, or finally, the superior or inferior extremity of the aforesaid interosseous spaces.

Thus from these vessels alone might be deduced the law, of which the origin of the obturator from the epigastric, or the sublingual from the facial, are familiar and important instances; viz. that varieties of arteries occur as the exaggerations of an ordinary anastomosis †: while it is no less evident that the deviations are compensative in the strictest sense; *i. e.* that the amount of blood entering the limb is no ways affected, for that an in-

* Such a vessel, occupying from a high origin the place of the artery, but more superficial than it, has on this account been mistaken for a "hard" pulse, and the patient depleted accordingly.

* Unless we considered the deep palmar arch as the anterior half of the carpal ring, a view which the comparative infrequency of the minute "anterior carpal arch" would almost allow of.

† It may be urged against such a generalization, "that it would scarcely include the varieties of those vessels which immediately spring from the heart or aorta: since anatomy shows the amount of their ordinary anastomosis, and the number, size, and regularity of the vessels effecting it, to be utterly disproportionate to the magnitude of these variations." But a reference to the aorta and branchial arches, from which they are developed in the fœtus, would again include them in the category of dilated inosculations.

crease of one is a diminution of some other vessel — or *vice versâ*.

The directness of these inosculations, and the frequency of these resulting irregularities together exert an important influence on surgical practice, which may be regarded in three points of view. Firstly, it necessitates unusual care in the ordinary operations; since we may open an artery of dangerous size, where we least expect it. Secondly, it renders operations undertaken on the vessels themselves liable to immediate non-success; for we may find only a twig where we expect an artery of influential magnitude. Thirdly, it may also cause their mediate failure; the width and number of the anastomosing channels rendering deligation of a trunk useless, by filling it in a very short space of time below the ligature. Fortunately, however, the same position that renders them more liable to injury affords somewhat of a substitute for the operation by also exposing them more directly to external pressure.

The diseases and injuries of the radial and ulnar arteries scarcely offer peculiarities sufficient to demand a special notice.

Aneurism as the result of disease, an extremely rare occurrence in the brachial artery, would appear to be here still more infrequent; and this remarkable immunity as compared with the lower extremity has been differently ascribed to a supposed greater vitality of the vessels nearer the heart, or with better reason to the less exposure of the arm to strains or shocks. Even this explanation, however, has so much imperfection about it, that it seems better to avoid theorising on the subject until more is known both of the physical relations of the different tubes to their central engine, and of the differences in the nature and rapidity of the nutrition of their coats, which may be presumed to exist.

False aneurism may occur in any part of their course as the result of puncture or incision of their coats; the sac of the tumour being formed by the nearest investing fascia, and lined by the areolar tissue of the neighbourhood condensed by the pressure of the contents. These consist of blood, which is usually in considerable quantities, and has experienced more or less coagulation subsequently to its discharge from the opening of the artery which occupies some part of the inner surface of the cavity. But neither in these points, nor in the treatment usually adopted is there anything which requires particular specification.

The disease of the arterial system generally, which constitutes so frequent and important a part of the series of changes included in the term "old age," of course includes these vessels. Ossification of the radial artery is by no means rare, although in this extremity it is very unusual to find it occluding the tubes or leading to senile gangrene. Here, from the superficial position of this vessel, it is often a valuable index by which an insight is afforded into the condition of other and more important arteries. In this latter stage of the change the vessel is rather larger than normal, very hard, thick, and tortuous: while the impulse of the heart communicated to it by its contents, and tending to efface these abnormal curves, often almost lifts it from its situation at each stroke. In an earlier stage of the affection it is much less easily recognised, but even here the tactus eruditus may sometimes appreciate the change; and though it is perhaps difficult to translate the sensation into words, such a pulse might be paradoxically described as being at the same time hard to the *touch*, and comparatively soft and yielding to the *pressure*, while its beats are associated with unusually little expansion, though they strike the fingers with more force.

(*William Brinton*).

RADIO-ULNAR ARTICULATIONS.

(*Articulations radio-ulnaires—Verbindungen des Ellenbogenbeins mit der Speiche.*)—Wherever the anterior extremity is modified to serve as an instrument of prehension, one chief part of the provision for greater freedom and facility of movement occurs as the correlative modification, not only of the two bones of the forearm, but also of the articulations which mutually connect them at their upper and lower extremities. In man, in whom the arm, losing its locomotive, attains its most complete prehensile development, the radius enjoys a very considerable degree of motion around the ulna by means of these joints. And by the alternate preponderance of either of the two bones in the wrist and elbow joints which are situated at their opposite extremities, this mobility of the radius is increased, while the freedom of movement predicable of it becomes extended to the hand which occupies its distal termination: and thus the rotatory movement which is gradually superadded to the ordinary flexion and extension of the limb finally reaches its maximum.

In each of these articulations we shall separately describe, 1. Its anatomical constituents—the several structures which serve to allow of, or to limit, motion. 2. The result of their functions—the movements of the joint.

(1.) *The upper radio-ulnar articulation*—whose elements are the head of the radius, the lesser sigmoid cavity of the ulna, the annular ligament, and a synovial membrane.

The round head of the radius—represents in shape the upper part of a cylinder, or rather a horizontal segment of an inverted cone, which becomes continuous below with the shaft of the bone by means of a constricted neck. It thus offers two articular surfaces: one, a shallow cup-shaped cavity which plays on the radial tuberosity of the humerus: another, the side of the cylinder, which has a linear measurement of about a quarter of an inch at its deepest part, where it corresponds to the lesser sigmoid cavity of the ulna and ends below in a prominent margin; elsewhere it is narrower; and subsides more gradually into the neck of the bone. These two smooth surfaces merge into each other at the angle where the base and circumference of the cylinder meet,

but it is to the latter only that our attention is at present directed.

The sigmoid cavity of the ulna— is a depression situated on the outer side of its upper extremity, and, in respect of its position, it might be expressed as an articular facet seated on the external margin of the coronoid process. In shape it is somewhat quadrilateral; and is concave in both directions, but most so in the anterio-posterior, which corresponds to the convexity of the head of the radius, and is also much the longest surface of the two. With trifling individual variations, it usually forms about the fourth of a circle. Superiorly, it is separated from the greater sigmoid cavity by a smooth elevation directed from before backwards: anteriorly, inferiorly, and posteriorly, the border of this articular surface overhangs the coronoid process of the ulna, the concave upper part of its anterior surface, and its posterior surface respectively. The junction of the two latter sides of its margin is marked by a strong ridge, which commences the external border of the bone: and, frequently the antero-inferior angle gives off a similar prominence; which, after a short course downwards, converges to join the preceding.

Articular cartilage covers these surfaces of the radius and ulna.

The annular or orbicular ligament—is the next constituent, and is a strong and somewhat cord-like band of white fibrous tissue, which completes the remaining three-fourths of the articular circle left unaccounted for by bone. Its width is about one third of an inch, its direction is horizontal like that of the sigmoid cavity. It arises behind from the posterior margin of this surface, and partly from its inferior border, uniting beyond these with the periosteum covering the surfaces of bone overhung by them. In front, it is inserted into the anterior margin in a similar manner. Above, it receives and is continuous with the anterior ligament of the elbow joint; farther outward, it is also joined by the external lateral ligament of the same articulation. Its lower border is free around the neck of the radius.

The synovial membrane is a process sent off from that which lines the articular surfaces of the elbow joint. A cul-de-sac passes downwards into the lesser sigmoid cavity, extending to its inferior extremity, but around the neck of the radius, and between it and the orbicular ligament, the remainder of this circular pouch has a diminished vertical extent; sufficient, however, to allow it to pass under the orbicular ligament, and appear from beneath its lower border.

The movement of the head of the radius at this articulation is one of simple rotation around its own axis; since the articular surfaces in contact with it together form a circle, in which its only movement can be a revolution. And, as above stated, about three-fourths of this circle is formed by ligament; the remainder by bone. But in addition to this chief provision for the limitation and direction of motion, the convex radial tuberosity of the humerus forms a kind of pivot, which is received into the cavity which occupies the upper surface of the radius, and, no doubt, steadies and assists the movement by tending still more to define the axis of this part of the bone. The articulation of the atlas with the odontoid process of the axis, offers many analogies to this of the radius and ulna both in the structure of the joint and in the resulting movements.

(2.) *The lower radio-ulnar articulation*—is, in many respects, the reverse of the preceding; since instead of presenting a cylindrical extremity of the radius revolving within a concave facet of the ulna, the latter bone itself offers a rounded termination, on and around the outer side of which the radius plays by a concave articular surface. The constituents of the joint are, the surfaces of the radius and ulna just alluded to; a fibro-cartilage which, with a kind of imperfect ligamentous capsule, forms the means of union of the bones; and a synovial membrane interposed between their articular surfaces.

The lower extremity of the radius—approaches somewhat to the form called by geometricians a parallelopiped. Its largest surfaces are the anterior and the posterior: the upper is joined and surmounted by the shaft of the bone, and the lower enters into the formation of the wrist joint. The outer side is occupied by the tendons of the muscles which extend the thumb: and the inner, which looks slightly upwards, articulates with the ulna.

This surface is quadrilateral, and of these the two antero-posterior sides are much the longest. The upper is nearly straight, the lower somewhat concave downwards to adapt it to the convex surface of the radio-carpal articulation; and they slightly diverge behind so as to make the posterior vertical border almost twice as deep as the corresponding anterior side. The articular surface itself is concave from before backwards, taking a curve whose extent is about one fifth of a circle.

The lower end or head of the ulna—is of even smaller size than the upper extremity of the radius which was previously described; a condition which is in conformity with its slight share in the wrist joint. The base of this cylindrical head has a smooth surface and is almost circular in shape; internally it offers a depression bounded by the prominent styloid process extending vertically downwards; externally, a margin defines its separation from the articular facet which occupies the outer part of the cylinder.

This convex surface is usually a little longer in the horizontal direction than the corresponding radial concavity, forming about a fourth of a circle; but in all other respects it is, as it were, moulded to it. Above, its margin projects beyond the constricted shaft. A layer of articular cartilage covers both these surfaces. Ligamentous fibres in sparing quantities, and with no very definite direction, unite the upper, anterior, and posterior borders

of these articular facets so as to result in a species of capsule.

The triangular fibro-cartilage is brought into view by removing the preceding ligament after laying open the wrist joint, and separating the two bones. Arising by a broad base from the sharp margin which separates the ulnar and carpal articulating surfaces of the radius, it passes inwards beneath the head of the ulna with continually diminishing width, until finally its apex is inserted into the base of the styloid process of this bone. At the commencement of this course it is nearly flat, though rather thicker at the margins than towards the middle ; indeed, it is by no means unusual to find a " perforation " or deficiency in this part — but towards its apex its thickness is so much increased as to give it almost a cord-like form where it joins the ulna. It belongs to the class of fibro-cartilages, and like most of these, the proportions in which its component tissues are mixed vary greatly in different parts : thus the centre consists chiefly of cartilage, while towards its periphery it is almost purely ligamentous. Its lower surface is covered by the synovial membrane of the carpal articulation, and is in contact with the upper surface of the cuneiform bone. Above, it corresponds to the lower extremity of the ulna, and the structure itself is the medium by which that bone takes its limited share in the wrist joint. Its borders, looking forwards and backwards, are united with the anterior and posterior ligaments of this articulation.

The synovial membrane, "*sacciformis*," as it is usually called, is large and loose, and is not only interposed between the radial and ulnar surfaces, but is also continued inwards beneath the extremity of the ulna, so as to cover it and the contiguous upper surface of the triangular fibro-cartilage. In passing from one of these apposed surfaces to the other, it lines, for a very short distance, the capsule and the two ligaments of the wrist joint which unite them.

The movement of the lower end of the radius may easily be deduced from the above description, where the shape of the articular surfaces and the attachments of the fibro-cartilage alike indicate a rotatory movement of this bone around the ulna ; since there is an almost complete correspondence between the apex of the ligament and the centre of that circle of which these articular surfaces would form a part.

But although the motion at either of these articulations is thus no very difficult deduction from their anatomy, the mutual consistency of the two, or the movement of the radius as a whole, seems to have been much less understood. The somewhat obscure language in which this has been described would allow us to imagine that a kind of rotation of this bone on its axis was supposed to result as the balance of the movements which obtain at the several joints. These anomalies and inconsistencies have been cleared up by Mr. Ward, in his very able work on Osteology; in which he points out that the axes of the head and neck of the radius above, and that of the head of the ulna below (the evident centres of rotation in each case) are continuations of each other, and form different portions of one and the same line, which is thus the real axis of the whole bone in its motions. In other words, the axis of the head and neck of the radius, prolonged downwards, would fall upon a point in the lower surface of the ulna, the centre of the circle whereof the sigmoid cavity is a part. And this, he urges, will alone explain how the partial rotation of the bone is altogether independent of any antero-posterior movement of its head, and occurs " without disturbance to the parallelism of the superior joint."

Thus we might imagine the articulations of the forearm to be the immediate consequence of two chief necessities of movement ; one of flexion and extension of this segment of the limb, another of alteration of aspect of the terminal segment or hand ; the latter can scarcely be accomplished in any other way than by semirotation. The conditions of powerful flexion and extension are, on the contrary, best suited by a more or less ginglymoid joint at each extremity ; and the shape of the interlocking surfaces which forms the chief security of such an articulation, would render it insusceptible of this partial rotation. These requirements, incompatible of fulfilment by one bone, are met by the addition of another, to which the hand is attached. And now a new necessity arises ; for the superadded lever must be associated with the pillar previously existing, so far as regards the first movement, but dissevered from it as regards the second. This is accomplished by giving the radius a very limited participation in the elbow joint, a very considerable one in the wrist ; and by making the ulna supply the terminal fixatures of the rotating shaft. The peripheral and complete condition of the upper attachment, the internal or centric and incomplete state of the lower, which, like the shaft itself, is here reduced to a part of a circle ; these are provisions which, like many met with in other parts of the body, at once economise means and preserve the symmetry of the limb.

Pronation and supination. — The extremes of this rotation of the lower extremity of the radius constitute the states of pronation and supination. So far as these result from the movements of this bone, they are not quite opposite aspects of its surfaces, or of those of the hand, since the angles which they mutually form in these conditions are scarcely equal to a quadrant and a half, or 135 degrees. And this fact, which the appearance of the articular surfaces alone would lead us to suspect, may be reduced to a certainty by the very simple experiment of bending the forearm, and then from extreme supination pronating the wrist, and comparing the lines formed by its anterior surface in both these positions with each other, so as to take the angle through which the surface has passed. Or better still, since it removes all suspicion of interference with the

muscles that effect pronation, fix the condyles of the humerus by any means, and then repeat the examination of these angles.

Pronation and supination may, however, be carried far beyond this limit of the radial motion; aided by powerful rotation of the humerus inwards and outwards respectively, the surfaces will attain to complete opposition of direction, or 180 degrees of intervening angle, and even to a variable distance beyond this which is, on an average, almost another quadrant.

It deserves also to be noticed, that these movements are often converted into rotation around the axis of the lower part of the forearm and wrist, by a somewhat similar humeral movement. For example, simultaneously with pronation, the lower end of the humerus is carried outwards and upwards, and a similar deviation is thus impressed on the ulna articulated with it, which extending to its lower extremity, results in the rotation of this part of the limb; *i. e.* in the completion of pronation, without the usual advance of the inner border of the forearm towards the median line of the body.

Dislocations of these joints.— At the upper of the two radio-ulnar articulations either bone may be thrown out of its place in several directions. Displacements of the ulna, however, chiefly affecting the elbow joint into which it so largely enters, are included amongst those of this part; and though those of the radius are, both in nature and effects, accidents of the radio-ulnar articulation, in practice it is very difficult to avoid considering together injuries which have so close a relation, albeit, strictly speaking, an accidental one. Hence the reader is referred for these to the article "Abnormal Conditions of the Elbow-joint."

At the lower joint the radius and ulna may be displaced from each other by external force, or by the violent action of the muscles in extreme pronation or supination: but the latter is a very rare occurrence. Looking to this articulation only, it might be difficult to define which bone was dislocated: whether, for instance, the ulna was "dislocated backwards," or the radius "dislocated forwards," since, in such a case, either of these phrases would equally express their altered relation to each other. It is most convenient to consider this question determined by the condition of the neighbouring wrist joint, and to instance those cases as dislocations of the radius where the extremity of this bone is located unnaturally forwards or backwards, both as regards the carpus and head of the ulna. And, similarly, where the wrist and radius preserve their ordinary relation, but the lower end of the ulna is displaced with respect to both; here it will be better to consider the ulna as the luxated bone, even though the accidents might sometimes resemble each other in their causes as well as mode of production.

The dislocation of the radius forwards is easily recognized by the styloid process of this bone and the trapezium no longer lying in the same vertical line; and by the situation of the extremity of the radius in front of the bones of the carpus, causing an unnatural prominence there. The luxation backwards would appear to be almost unknown, a reversal of these signs would indicate it. In both, the relative position of the ulna and wrist is little affected.

In the dislocation of the ulna, the ordinary connection of the hand and radius being kept up, the pronation or supination of the limb becomes a feature of a very striking kind. The signs of the luxation backwards are extreme pronation, the head of the ulna projecting beneath the skin at the back of the forearm, and the styloid process of this bone occupying a line posterior to the border of the wrist or the cuneiform bone. The dislocation forwards is of extreme rarity, but the above marks, *mutatis mutandis*, would leave little room for doubt as to the nature of the accident.

The *diseases* of these articulations offer no peculiarities which deserve a separate description.

(*William Brinton.*)

REN* — THE KIDNEY (Gr. νεφρος; Germ. *Niere;* Fr. *Rein;* It. *Ren*). — The kidney is a double gland, having for its office the secretion of a liquid which in common language is called urine. Since the time of Malpighi, the structure of this organ has excited in a more than ordinary degree the interest of the anatomist and the physiologist; but this interest has been much increased by the researches of Mr. Bowman, whose admirable paper on the "Structure and Use of the Malpighian bodies of the Kidney†," while it has placed the kidney in the list of those organs whose anatomy is most clearly demonstrated, has acquired for its author a reputation which will endure so long as anatomical science is cultivated.

This article is divided into three parts; the first part, containing a brief account of the general form and structure of the renal organs in the lower animals, as introductory to the second part, which contains an account of the anatomy and physiology of the human kidney, with references to such facts in the minute structure of the kidneys of some of the lower animals as will serve to throw light upon the structure and office of the organ in man. The third part contains an outline of the pathology of the kidney.

* In explanation of the use of the Latin word REN as the heading of this article, the Editor deems it necessary to state, that the article was undertaken some years ago by a gentleman who failed to complete his engagement in time for its publication under the title KIDNEY; it was found necessary, consequently, to postpone the subject, and to adopt the present title. The article was subsequently committed to other hands, in which it shared a similar fate to that which it experienced at first, and it ultimately fell into the hands of its present able author. — ED.

† Philosophical Transactions, 1842.

PART I.

RENAL ORGANS IN THE LOWER ANIMALS.

Under this head we purpose to refer briefly to such facts in the anatomy of the urinary organs of the lower animals as will serve to render more intelligible the structure and office of the human kidney.

Invertebrata. — That the excretion of urine is a function of great importance is sufficiently manifested by the fact that a special organ for the performance of this office is found in animals very low in the scale of organization.

In *insects* the urinary glands are usually in the form of long and delicate tubes, but sometimes present the structure of groups of round vesicles, as in the *Carabus*, in which the common duct terminates in a small dilatation; the urinary bladder is likewise present in the water-beetles. The excretion is poured into the termination of the intestine, or evacuated contiguous to the anus.*

In the *Arachnida*, "two long and slender urinary tubes communicate with the beginning of the cœcum, which seems to stand to them in the relation of an urinary bladder."

In the *Lamellibranchiata*, "the returning veins of the body form a remarkable plexus at the base of the gills near the pericardium, which assumes the form of a distinct glandular organ in the higher *Bivalves.* The secretion of this venous body abounds with calcareous particles, and the gland was called by Poli the secreting organ of the shell. Modern analysis has detected a large proportion of uric acid in the peritoneal compartment enclosing this venous plexus, and has thus determined it to be the renal organ." †

In the *Gasteropoda*, the urinary gland is a follicular organ attached to the walls of the branchial cavity. In some species of Paludina the duct dilates to form a small receptacle.

Among the *Cephalopoda*, the *Nautilus* presents the supposed analogues of the urinary organs in the form of clusters of glandular follicles of a simple pyriform figure, three clusters of such glands contained in membranous follicles being situated on each of the four branchial veins. The walls of the receptacles exhibit in some parts a fibrous texture, apparently for the purpose of compressing the follicles and discharging their secretion into the branchial cavity by apertures at the base of the gills. The analogues of these organs exist in the higher Cephalopoda, in which they are considered to act as kidneys by Mayer; and Prof. Owen remarks‡, "it is more philosophical to conclude that the organs of so important an excretion should be present in all the class, than that they should be represented by the ink-gland and bag, which are peculiar to one order."

Vertebrata. — In *Fishes* the kidneys are long and narrow; they are situated on each side of the mesial line, immediately beneath the bodies of the vertebræ, and extending through the whole or the greater part of the dorsal region of the abdomen. They are usually broadest and thickest anteriorly, while they become smaller and approach each other as they extend backwards. Sometimes a single common ureter quits the coalesced hinder ends of the kidneys. In some species the kidneys are thickest at their posterior ends. They have not a well-defined capsule, but their ventral surface is immediately covered by an aponeurotic membrane, against which the peritoneum and the air-bladder, when present, are applied. The renal tissue presents a uniform appearance without division into a cortical and medullary portion. The urinary tubules pass immediately into the ureter without the intervention of a pelvic cavity. Malpighian bodies exist in the kidneys of the fish as in those of the higher vertebrata; the structure of these bodies will be fully explained in a subsequent part of this article. The kidneys are supplied throughout their entire length by numerous small branches from the abdominal aorta. In addition to the arterial blood thus supplied to the kidneys, these organs also receive a large quantity of blood from the *veins* which proceed from the posterior part of the body. This peculiar system of veins, which was discovered by Bojanus, and more fully described by Dr. Ludovic Jacobson*, is found in birds and reptiles as well as in fishes. In its primary form it undergoes, according to Jacobson, three degrees of modification. The *first modification* exhibits the following form: — From the skin and muscles of the middle part of the body branches arise, which form several trunks, passing separately to the kidneys.

In the *second modification*, the veins which return from the posterior part of the body are received into this separate system. The caudal vein, which brings back the blood from the skin and muscles of the posterior part of the body, divides into two branches, which, having received some veins returning from the middle part of the body, pass to the kidneys of each side, and distribute their branches in the substance of these glands.

In the *third modification*, the veins of this system are formed in the same manner as in the preceding, excepting that the caudal, or other vein returning from the posterior part of the body, gives off a branch to the *vena portæ.*

The blood, returning from the middle and posterior part of the body in the first and second modification of this system, is conveyed only to the kidneys; but in the third it is divided between the kidneys and the liver. The inferior *vena cava* of the common venous system, in the second and third modification is composed of the veins returning from the kidneys and testicles or ovaries. In the first modification, the caudal vein receives the veins returning from the kidneys, is united

* Professor Owen's Lectures on Comparative Anatomy.

† Ibid.

‡ Lectures on Comparative Anatomy.

* Edinburgh Medical and Surgical Journal, vol. xix.

with the veins of the testicles or ovaries, and in this manner forms the inferior vena cava.

The above is a general description of this peculiar system of veins. With reference to its existence in fishes, it will suffice to add, that in different genera this venous system appears in all its modifications.

In *Reptiles*, the kidneys are generally situated very far back, even within the cavity of the pelvis, where a sacrum exists, as in the Chelonian and Saurian orders; and in these tribes they are very partially covered by the peritoneum being firmly imbedded in the sacral region. But in serpents, in consequence of the elongated form of the body, and the complete flexibility of every portion of the spine, the kidneys are peculiar both in their position and general structure. The kidneys of an Ophidian are not placed upon the same level, but the right is situated much more anteriorly than the left ; a circumstance which much facilitates the packing of the abdominal viscera, and contributes greatly to ensure the free movements of the vertebral column at this place. For the same reason the kidneys of a serpent are divided into numerous lobes of a compressed reniform shape, placed in a longitudinal series upon the external surface of the ureter, and loosely connected to each other and to the spine by cellular tissue and a fold of the peritoneum.* The kidneys of reptiles, like those of fishes, have no distinction of cortical and medullary substance ; and the urinary tubules pass immediately from the substance of the kidney into the ureter.

The peculiar venous system described by Prof. Jacobson is found in reptiles under the form of the third modification ; that namely, in which the blood returned by the veins from the back and the posterior part of the body, is divided between the kidneys and the vena portæ. The exact distribution of these veins in the substance of the kidney of the Boa has been clearly demonstrated by Mr. Bowman, as will be shown, when we come to speak of the minute anatomy of the kidney. The arterial branches, which are comparatively of small size, are derived from the abdominal aorta.

In *Birds* the kidneys are elongated in form, commencing immediately below the lungs, and extending symmetrically on each side of the spine, as far as the termination of the rectum. The posterior surface is moulded into the cavities formed by the bones on which it rests. The ureter proceeds from the anterior aspect, the secreting tubules passing immediately, as in fishes and reptiles, into the ureter, so that there is no pelvic cavity in the organ, nor any division into cortical and medullary substance. The outward form of the kidney is very various, and the surface is divided in different species into a variable number of lobes. Each kidney is invested by a delicate capsule, which extends into the substance of the gland between its lobular divisions. Their texture is much more friable than in mammalia, readily yielding under the pressure of the finger, to which they give a granular sensation as their substance is torn asunder.*

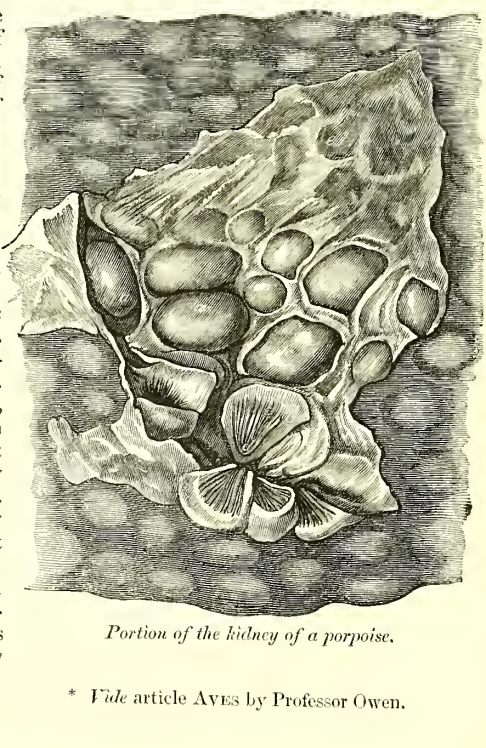
* Professor Rymer Jones's Animal Kingdom.

The peculiar venous system already referred to is described by Jacobson as existing in birds under the form of the third modification. But the arrangement of the veins differs from that observed in reptiles in this respect, that the crural vein after giving off a superior branch to the superior lobe of the kidney, and an inferior to the ischiatic vein, sends a middle branch direct to the vena cava. All the blood, therefore, which in birds returns from the posterior part of the body, is carried partly to the kidneys, partly to the portal vein, and partly, but in small quantity, is conveyed in a direct manner to the vena cava. There are no regular emulgent arteries in birds, the kidneys deriving their arterial blood from various branches of the abdominal aorta.

The kidneys of *Mammalia* present one character which is common to the whole tribe, and by which they are distinguished from the other classes of vertebrata. The character alluded to consists in a division of the substance of the gland into two portions, a cortical and a medullary, the former being the secreting part and containing, as will be more fully shown hereafter, tubes which are very tortuous, while in the latter the tubes are straight, forming minute excretory ducts, through which the secreted products are conveyed into the ureter.

In many genera the kidneys are composed of a number of separate lobules or renules, (*fig.* 142, *a a a*), each lobe consisting of a cor-

Fig. 142.



Portion of the kidney of a porpoise.

* *Vide* article AVES by Professor Owen.

tieal (b) and a medullary substance (c), the latter terminating in a mamillary process (d) which is received into an infundibular offset from the ureter. All the lobules are thus connected with the ureter, forming a clustered mass like a bunch of grapes. The entire kidney is invested by a cellular capsule (e), a deep layer of which (f) passes into the fissures between the lobules, and in the substance of this interlobular tissue the vessels are imbedded. There is no anastomosis between the blood-vessels of neighbouring lobules, as shown by the circumstance that when the artery in any of them has been obstructed in an injected preparation they remain uninjeeted.* This form of kidney is observed in amphibious Carnivora, as the otter and the seal tribes; it is also found in the bear, and still more remarkably in the cetaceans. The lobular division of the kidney, which in these animals is a persistent condition, exists in the embryo of all the mammalia. In process of development in the greater number of genera, the lobules coalesce, and thus form a solid glandular organ having a smooth continuous surface, and presenting in the normal state no trace of the original lobular divisions. The kidney of the ox presents a condition intermediate between the lobulated kidney and the solid organ of man and most other mammiferous genera. In this animal the medullary portion of the kidney has coalesced, while the cortical part is marked out by deep interlobular fissures. The coaleseence of the lobules appears to have been arrested at a certain period of its progress. The manner in which the tubes open into the pelvis of the solid kidney admits of some variety. In some genera they open on a eontinuous concave surface, as in the horse and ass; in others on a continuous ridge, as in the dog. A more common termination is in a conical projection, the apex of which is received into a calyciform cavity in the pelvis of the kidney. In some genera, as in the human subject, there are several of these conical processes in each kidney; while in other animals, all the tubes of the gland converge to a single cone, as in the lion, the racoon, the kangaroo, the monkey, the squirrel, &c.

The renal artery, derived from the abdominal aorta, enters the hilum of the kidney. The veins generally follow the arteries, but there are exceptions to this rule. In the lion kind the cat kind, as also in the hyæna and in the seal, perhaps one half of the veins yet on the external surface, over which they pass, enclosed in a doubling of the capsule, and so join the trunks from the inside just as the latter are passing out from the hilum.†

PART II.—THE HUMAN KIDNEY.

We now proceed to give a detailed account of the anatomy of the human kidney, with such facts in the minute structure of the gland in certain of the lower animals as serve to throw light upon the structure and office of this important organ in man.

Form.—The form of the kidney being so familiar as to serve for a standard of comparison with other objects, it appears needless to speak of its resemblance to a Freneh bean, the concave margin being directed towards the spine, while the convex margin, which is thick and rounded, is directed outwards. The upper extremity is usually broader and thicker than the lower. The anterior surface is eonvex; the posterior is flatter and rests upon the muscles and fascia. The two kidneys are occasionally, but very rarely, united by a band of renal substance, extending transversely across the spine in front of the aorta. The two glands thus united have the form of a horse-shoe, the concavity of which is directed upwards.

Dimensions and weight.—The average length of the kidney is from 4 inches to $4\frac{1}{2}$ inches, its breadth 2 inches, and its thickness 1 inch. Its usual weight is from 3 to 4 ounces.

Position and relations.—The kidneys are situated deeply in the lumbar region on each side of the spine, occupying a spaee corresponding to the last dorsal and the two or three upper lumbar vertebræ. The right is usually somewhat lower than the left, being depressed, as it were, by the liver, which is placed just above it. Occasionally one or both kidneys may be found very much out of the natural position, being situated either in front of the spine, or much below the usual position, even as low as the cavity of the pelvis. The kidneys are placed somewhat obliquely, the upper extremities being inclined towards the spine and approaching nearer to each other than the lower. They are imbedded in a layer of adipose tissue, the quantity of which is very variable, being thick and abundant in fat subjeets, while in those who have died much emaciated, the loose investment of reticular tissue presents scarcely a trace of fat.

The anterior surface of each kidney looks somewhat outwards; it is partly covered by the peritoneum, chiefly at the upper extremity, and more on the right side than on the left. The right kidney is covered by the aseending colon, and the left by the descending colon. The anterior surface of the right kidney is also in contact with a small portion of the duodenum, and is covered by the right lobe of the liver. In some instances the gall-bladder covers a large part of the anterior surface of the right kidney. The left kidney at its upper part lies in contact with the spleen, and is covered by the great end of the stomach when this viscus is distended.

With reference to diagnosis, it is important to bear in mind the proximity of the kidneys to the colon, and the possibility of disease extending from one organ to the other. Abscess of the kidney has in many instances been known to burst into the colon, and it is not improbable that ulceration of the colon, either simple or malignant, might extend backwards into the kidney.

* This is seen in the kidney of a walruss, No. 1265 in the Museum of the College of Surgeons.

† Hunterian Museum and Catalogue.

The *posterior surface* of the kidney looks somewhat inwards; it rests upon the quadratus lumborum muscle, from which it is separated by the anterior division of the tendon of the transversalis; it is also in contact with the diaphragm, which separates it from the two or three last ribs, and with the psoas muscle, which separates it from the spine.

From a consideration of these relations, it will be seen that exploration of the kidney, with a view to detect enlargement or tenderness, may best be made in the lumbar region on either side. It will also be evident that abscess originating in the kidney may extend backwards, and become diffused amongst the muscles in this region, or that it may approach the surface, and discharge itself by an opening in the loins. Cases of this kind are known to occur; and when renal calculi have been the exciting cause of the suppuration, these have escaped through the same opening in the lumbar region.

The *circumference* of the kidney presents, 1st, an external border, thick, convex, semi-elliptical, and directed outwards, backwards, and upwards; 2nd, an internal border, directed inwards, forwards, and downwards, and presenting about its middle a deep notch or fissure, the *hilum*, as it is sometimes called. This notch is more marked posteriorly, where it corresponds to the commencement of the ureter and the pelvis of the kidney, than anteriorly, where it corresponds to the renal vein. The notch usually contains some adipose tissue, which passes in with the blood-vessels, and occupies the space between the substance of the kidney and the pelvis.

Of the *extremities* of the kidney, the superior, as before stated, is larger than the inferior, and directed somewhat inwards. It is immediately covered by the supra-renal capsule. The liver is above the right, and the spleen above the left. The inferior extremity of the kidney is directed somewhat outwards, and has below it, but at some distance from it, the crest of the ilium.

The *ureter*, or *excretory duct* of the kidney, extends from the hilum of this organ to the base of the bladder. It is a cylindrical canal, with whitish, elastic walls, varying in size from that of a crow-quill to that of a goose-quill. It is usually dilated at its commencement, narrowed in the middle of its course, and again dilated before its entrance into the bladder.

Its *direction* is obliquely downwards and inwards to the sides of the base of the sacrum; it then passes almost horizontally forwards between the layers of peritoneum forming the posterior ligament of the bladder; lastly it is directed inwards to the side of the base of the bladder, where it takes an oblique course through the wall of that organ, to open on its inner surface by a narrow orifice in one of the posterior angles of the trigone.

The *relations* of the ureter are the following: — In the notch of the kidney the ureter lies behind the renal vessels. From the pelvis of the kidney to the base of the sacrum it is in contact with the anterior border of the psoas muscle; it is covered by the peritoneum, and is crossed obliquely by the spermatic vessels. The right ureter has the inferior vena cava on its inner side. On a level with the base of the sacrum, each ureter crosses the common iliac, and below this the external iliac artery and vein. In the pelvis the ureter lies in contact with the wall of this cavity, being covered by peritonæum, and crossing successively the umbilical artery or its obliterated cord, the obturator vessels, the vas deferens in the male, and the superior and lateral part of the vagina in the female. In that part of its course which is included in the wall of the bladder the ureter is very close upon the neck of the uterus, and is thus liable to become involved in cancerous disease of that organ.* That part of the ureter which lies in contact with the anterior border of the psoas may become affected by disease extending from the substance of the muscle. The pathological museum of King's College contains a preparation in which an abscess, occupying the substance of the psoas muscle, has opened into the ureter.

The ureter has two distinct coats or membranes. 1. An internal mucous membrane, continuous above with the mucous lining of the pelvis of the kidney, and below with that of the bladder. 2. An external fibrous coat, continuous above with the capsule of the kidney and with the pelvis, and below with the muscular coat of the bladder. The minute structure of the coats of the ureter will be described in a subsequent part of this article.

Blood-vessels of the Kidney.—The *emulgent* † *or renal arteries* are the largest branches of the abdominal aorta, from which they proceed at nearly a right angle. Their origin is about half an inch below the superior mesenteric artery, the right being frequently somewhat lower and longer than the left. Each renal artery passes obliquely downwards, backwards, and outwards towards the hilum of the kidney, giving off in its course branches to the supra-renal capsule, to the ureter, and to the surrounding cellular membrane. At the pelvis of the kidney the artery usually lies between the vein and the ureter, the former being in front of, and the latter behind, the artery. In the hilum of the kidney, where the artery is surrounded by reticular and adipose tissue, it breaks up into four or five branches, and these again subdivide into smaller branches, most of which pass in front of the pelvis of the kidney, while a smaller number pass behind this part; their course and distribution in the substance of the kidney will be described in connexion with the structure of the gland. The right renal artery is covered at first by the vena cava, and then by its corresponding vein; the duodenum and pancreas are also in front of it. It crosses the spine and the right psoas muscle. The artery

* Cruveilhier, Anatomie Descriptive.

† Insulsa theoria, quâ urinam vasis secretam ex papillis quasi *emulgendo* prolici credebatur, ea sic denominandi ausam dedit. Schumlansky, de Structura Renum.

on the left side is covered by its corresponding vein, and crosses the left psoas muscle.

The renal arteries occasionally present some anomalies as to their origin, mode of division, or number. In some instances they arise below the usual situation, from the aorta, or even from the common iliac or hypogastric artery. The two last-mentioned origins are usually associated with an unusual position of the kidney, either in the iliac fossa or in the cavity of the pelvis. Meckel* has observed the two renal arteries arising by a common trunk from the *anterior* part of the aorta.

The artery sometimes divides into two or more branches immediately after its origin, in which case one branch usually leaves the others to enter one of the extremities of the kidney. This irregularity forms an approach to another, which consists in an increase in the number of renal arteries, each kidney receiving two, three, or four branches having a separate origin from the aorta.

The *emulgent or renal vein* commences in the substance of the kidney by numerous minute branches, which unite into four or five trunks, and these again unite to form a single trunk, either in the fissure of the kidney, or at a short distance from this point. The vein passes almost transversely inwards to the vena cava, the right vein being shorter than the left, on account of the position of the vena cava to the right of the spine; the junction of the right vein with the cava is also somewhat higher than that of the left. The vena cava presents a marked increase of size immediately after receiving the renal veins. Each renal vein is placed in front of the corresponding artery ; the vein on the left side crosses over the aorta. The renal veins receive some small branches from the supra-renal capsule, and from the reticular and adipose tissue surrounding the kidney, and the left renal vein is usually joined by the spermatic of the same side.

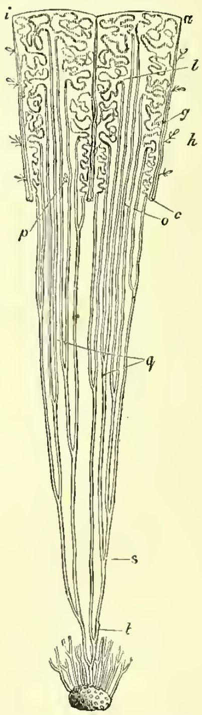
The *lymphatics* of the kidney are but little known ; they are said to consist of a superficial and a deep set, the latter being the most abundant ; they pass from the fissure of the kidney to the lymphatic glands which surround the aorta and the vena cava.

The *nerves* of the kidney are very numerous, consisting of several small branches from the lower and outer parts of the semilunar ganglion and solar plexus, joined by the descending branches of the small splanchnic nerve. The renal plexus thus constituted accompanies the artery into the fissure of the kidney. This plexus sends numerous filaments to the spermatic plexus, and hence probably the sympathetic connexion which exists between the testicle and the kidney.

Structure of the Kidney. — In order to examine the general structure of the kidney, it is necessary to make a longitudinal section from the convex towards the concave border. On examining the surface of such a section, it will be seen that the substance of the kidney is composed of two portions, differing from each other in their general appearance and arrangement ; an external *cortical*, and an internal *medullary portion*. It will also be seen that the entire organ is invested by a *fibrous capsule*, which at the hilum becomes continuous with the *pelvis* of the kidney and with the ureter. It appears desirable to examine the general appearance and structure of these several parts before proceeding to the consideration of the minute anatomy of the kidney.

The *cortical substance* forms a layer about two lines in thickness, which occupies the surface of the kidney, and sends inwards prolongations, from one to three lines in thickness, between the conical divisions of the tubular substance. The colour of the cortical substance is much influenced by the quantity of blood which it contains. It is usually of a lightish red colour, but in anæmic subjects it very frequently presents a yellowish-white appearance, this being the colour of the renal tissue when deprived of blood. The cortical substance is of a softish consistence, readily tearing beneath the pressure of the finger, and

Fig. 143.



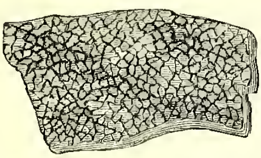
Section from the surface of the kidney to the apex of one of the medullary cones. The plate is introduced partly to show how accurate was Schumlansky's knowledge of the general structure of the organ. *c*, *g*, blood-vessels ; *h*, the artery terminating in a cluster of Malpighian bodies ; *q*, *s*, *t*, straight tubes, with their dichotomous divisions ; *o*, bundles of these passing towards the surface and then becoming tortuous ; *p*, section of blood-vessels. (*After Schumlansky.*)

* Cruveilhier, Anatomie Descriptive.

presenting an irregular granular surface. In an injected specimen there may be seen scattered through the cortical substance, in every part, except near the surface of the organ, numerous minute red granules; these bodies have been named after the distinguished anatomist who discovered them, the Malpighian bodies of the kidney. The great mass of the cortical substance is made up of secreting tubules, the existence of which was first clearly demonstrated by Ferrein; hence they have been named the tubes of Ferrein. The course of these tubes is, for the most part, very tortuous; but near the basis of what will presently be described as the pyramids of Malpighi there is an appearance, visible even to the naked eye, of straight lines radiating towards the surface of the kidney; these lines result from bundles of tubes passing upwards from the pyramids of Malpighi and retaining their straight course until they reach the surface, where they become tortuous, and pass backwards deeply into the cortical substance (*fig.* 143).

The surface of the cortical portion frequently presents an appearance of lobules, somewhat similar to those of the liver. The form of these lobules varies considerably; in some instances they are circular, but very commonly they have a pentagonal or hexagonal outline; they are usually about $\frac{1}{8}$ of an inch in diameter (*fig.* 144).

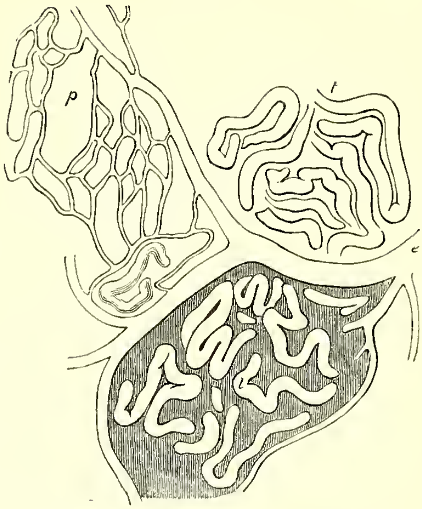
Fig. 144.



Portion of the surface of the kidney, showing the lobulated appearance which results from congestion of the venous radicles. Natural size; from a specimen prepared by Mr. Bowman.

This lobulated appearance of the surface is produced by the venous radicles which are dispersed at nearly equal distances throughout the cortical substance, each receiving the blood, as will presently be shown, from the plexus surrounding the convoluted tubes. These radicles unite in an irregularly arborescent figure, anastomose, and form the several branches of the renal vein. Those on the surface have a tendency to converge towards a central vessel, which then dips into the interior to join the trunks of the renal vein. Thus are formed the stellated vessels, which are often very conspicuous in diseased specimens, when there has been an impeded circulation through the veins of the kidney. Between the arms of these stellæ the convoluted tubes are visible on the surface (*fig.* 145). Ferrein supposed each of these lobules to form the base of a pyramid, the apex of the same being at the extremity of a mamillary process, and he believed that such an elongated pyramid might be traced continuously from one part to the other, the tissues radiating from

Fig. 145.



Portion of the surface of the human kidney injected by the artery. *t, t*, tortuous tubes as seen on the surface; *p*, capillary plexus surrounding the tubes; *e*, a branch of one of the stelliform veins. Magnified forty-five diameters. (*After Bowman.*)

a point in the mamillary process, through the cortical substance, to one of the lobular divisions on the surface. Mr. Bowman's preparations show that "each lobule contains many tortuous ducts with their capillaries, but the convolutions of any one duct are not confined to a single lobule." Hence it is manifest that there is no natural division of the renal substance corresponding with the supposed "pyramids of Ferrein," and there appears no reason for retaining a name which is not expressive of any fact or definite idea.

The *medullary substance* or, as it is sometimes called, the *tubular portion*, is of a firmer texture and darker red colour than the cortical portion, and presents itself under the form of cones or pyramids, (pyramids of Malpighi,) the bases of which are directed towards the surface of the kidney and continuous with the cortical portions, while the apices, which are called *mamillary processes*, or *papillæ*, are free and directed towards the cavity of the pelvis. The number of these pyramids has been variously stated by different anatomists; their number is not constant, but it is usually about twelve or fifteen in each kidney. Some of the pyramids are compound, being formed by the union of two, which have one common mamillary termination. The number of mamillary processes is therefore less, by four or six, than that of the pyramids. The cut surface of each pyramid has a striated appearance, being composed of tubes which subdivide and radiate in passing from the apex towards the base, where they merge into the cortical substance. These tubes are com-

monly named the tubes of Bellini, that anatomist having been the first to show their true tubular character; they are united by a firm network of fibrous tissue in the substance of which there are some large veins, which take, for the most part, a straight course between the tubes. No Malpighian bodies exist in the medullary cones.

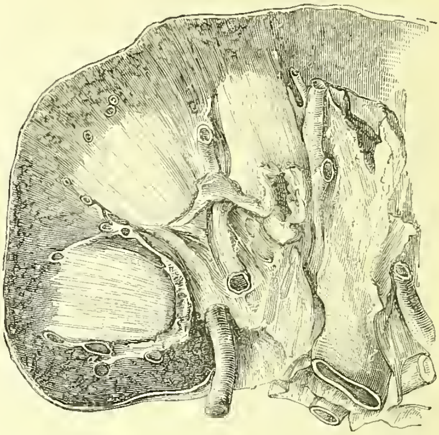
The *capsule* of the kidney is a firm, white, fibrous membrane adherent by its external surface to the adipose tissue in which the kidney is imbedded, and connected by its internal face to the entire surface of the kidney. It sends numerous fibrous processes into the cortical substance, and small vessels pass from the substance of the kidney into the fibrous capsule. These connecting bands between the kidney and its capsule are easily torn when the capsule is stripped from the surface of the kidney. At the hilum of the kidney the capsule becomes continuous below with the ureter and above with the fibrous layer of the pelvis; at the same point the blood-vessels receive an investment from this fibrous membrane, which is continued upwards with them until they finally break up into minute branches about the bases of the pyramids.

Calyces, Infundibula, and Pelvis.—The calyces are membranous or fibro-mucous cylinders which receive in their upper extremities the apices of the mamillary processes. Where the membrane is reflected over the apices of the cones, it is perforated by numerous orifices of the tubes of Bellini, from which a liquid may be seen to escape when pressure is applied to the cones. The calyces are less numerous than the mamillary processes, two or three mamillary processes being occasionally received into one calyx. The calyces unite into three small tubes, one corresponding with each extremity and one with the central portion of the kidney; these have somewhat of a funnel shape, and are called *infundibula.* The infundibula soon unite to form the *pelvis* of the kidney, which is a membranous reservoir of a flattened oval figure, terminating below in the ureter. The pelvis and infundibula are usually surrounded by loose reticular and adipose tissue. The blood-vessels of the kidney are placed in front of these parts. The fibrous and mucous coats of the ureter are continuous with those of the pelvis, infundibula, and calyces.

Before passing on to the description of the minute structure of the kidney, it is desirable to examine the position of the blood-vessels about the medullary cones, so far as this can be ascertained by the unaided eye.

The renal artery, as it enters the hilum of the kidney, breaks up into four or five branches, and these again subdivide, a few of the branches passing behind the pelvis, while the greater number remain in front; they pass upwards between the calyces enclosed in folds of the fibrous membrane, and so they come in contact with the sides of the medullary cones. Each cone appears to be supplied by two arterial branches, which, passing up one on each side, form an anastomosing arch over the base of the cone (*fig.* 146). From this arterial arch branches proceed in all di-

Fig. 146.

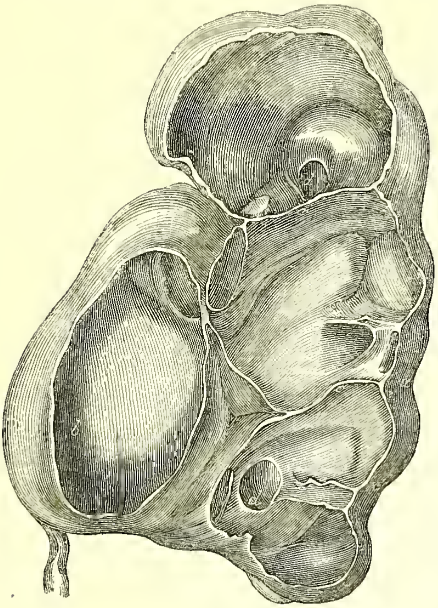


Section of the kidney, showing the position of the arterial and venous branches by the sides of the medullary cones. *a, a, a, a,* arteries; *b, b, b,* veins.

rections, the greater number passing into the cortical substance. The venous branches in this situation likewise form arches over the medullary cones, and have the same general arrangement as the arteries; they unite into four or five trunks which are placed in front of the pelvis. There is no anastomosis between the arteries of neighbouring cones; each medullary cone, with its investing cortical substance, corresponds with one of the separate lobules of the embryo kidney; and although in the fully developed human kidney, scarcely any trace of the original lobular division remains, yet the separation of the lobules, so far as their vessels are concerned, remains as complete as it is in the permanently lobular kidney of the porpoise. When an injection is thrown into the vessels of one lobule, that lobule only is injected, without the transfer of the injection through anastomosing vessels to neighbouring lobules. Obstruction of the artery passing to one lobule will effectually prevent the injection of that lobule, while the surrounding parts are completely injected. It occasionally happens during life that the vessels supplying one or two lobules become obstructed, and as a consequence of this obstruction those lobules become atrophied while the rest of the gland is perfectly nourished. Additional evidence of the complete isolation of the lobules of the human kidney is afforded by certain other pathological conditions, which may, with advantage, be briefly alluded to in this place. *Fig.* 147 represents a section of a kidney, the glandular structure of which has been destroyed by cysts developed in its substance; the part which remains is a framework or skeleton, consisting of the capsule (*a*) continuous below with the pelvis (*b*), which is much dilated,

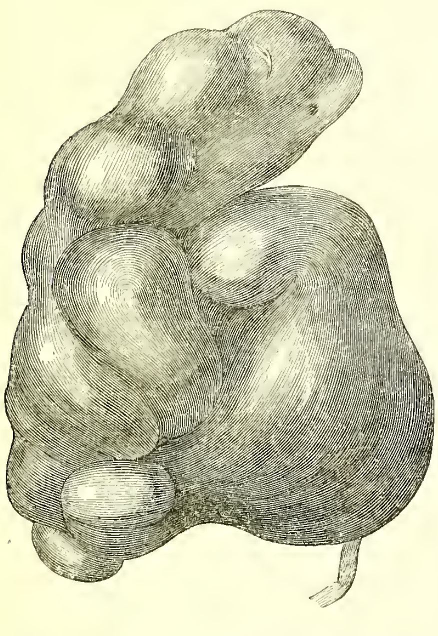
while the same fibrous membrane is prolonged continuously through the substance of the

Fig. 147.



kidney to the surface ; the septa (*c,c,c*), which thus divide the kidney into the various closed

Fig. 148.



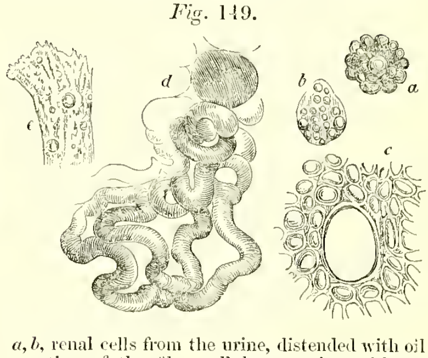
compartments, occupy the position of the original interlobular fissures in the embryo kidney, and are analogous to the deep layer of the fascia with its interlobular prolongations which exist in the kidney of the porpoise.* In this instance the tissue has been condensed and thickened by disease. At *d, d* there may be seen the rounded openings through which the apices of the medullary cones projected into the calyces. The lobulated character of the surface of the same kidney is represented in *fig.* 148 ; the depressions correspond with the fibrous septa, and indicate the position of the original interlobular fissures ; the convexities correspond with the lobules, and have been rendered prominent by a liquid accumulation in the closed cavities formed, as above described, in the substance of the organ.† Reference will hereafter be made to some other morbid conditions of the human kidney which have peculiar characters impressed upon them by these interlobular septa, which are in fact the persistent remains of that interlobular cellular tissue, which is permanently distinct in certain tribes of mammalia, while in most animals of this class, as in the human subject, it remains as a distinct and easily recognised tissue only during fœtal life. In the completely formed kidney it is blended with and concealed by the surrounding tissues, and manifests its presence as it were indirectly, by the peculiar characters which it impresses on the structure of the kidney as shown by the results of injection or in the course of certain pathological changes.

Minute Structure. — In this division of our subject, we have to consider, in succession, the following structures.

1st, The *fibro-cellular matrix;* 2ndly, The *tubes*, their course, division, and termination ; 3rdly, The *Malpighian bodies*, their connexion with the blood-vessels, and with the tubes ; 4thly, The *epithelium*, in different parts of the surface over which the urine passes, commencing with that of the Malpighian bodies, and terminating with that of the pelvis and ureter.

The *fibro-cellular matrix* of the kidney has been well and accurately described by Professor Goodsir.‡ It exists throughout every part of the renal structure. (*Fig.* 149, *c*) represents

Fig. 149.



a, b, renal cells from the urine, distended with oil ; *c*, portion of the fibro-cellular matrix, with one

* *Vide antè*, p. 233.

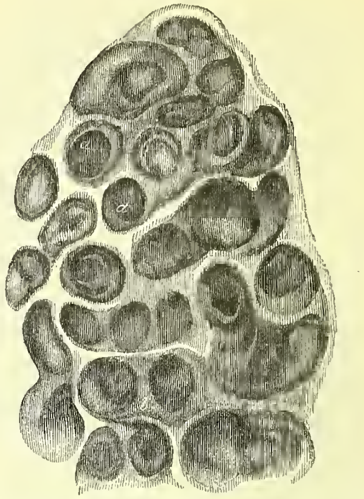
† The drawings are about one-third the natural size ; the preparation from which they are taken is contained in the Museum of King's College.

‡ Monthly Journal of Medical Science, May, 1842

large oval space, which contained a Malpighian body, and several smaller meshes in which the convoluted tubes were packed; *d*, Malpighian capsule and tube, filled with blood from the Malpighian capillaries; *e*, fibrinous mould of a urinary tube entangling oil globules, from the urine.

a portion from the cortical substance.) It is best examined in a thin section which has been macerated in water for a few minutes, so as to wash away the tubes and Malpighian bodies. The matrix then appears in the form of a fibrous network, the meshes of which have, for the most part, a circular outline. The smaller meshes are of pretty uniform size, and are accurately filled by the tubes, each tube in its tortuous course passing through very many of the cells formed by this curious and beautiful structure. The meshes do not occupy any one plane or position rather than another, but in whatever direction the section of the cortical substance is made, the same regular network presents itself. When the tubes are in sitû, they often appear to be mapped out, as it were, into regular circular or oval portions; an appearance which has, doubtless, confirmed some observers in the erroneous notion that the tubes terminate in blind extremities. This apparent isolation of the different parts of what is in reality a continuous tube, is very much influenced by the condition of the tube itself. In the normal state, the colour of the tubes often contrasts with that of the matrix, which when free from blood is of a whitish colour, so that the tubes are visible through the substance of the matrix, and the observer can trace the continuity of the tube between the different meshes of the tissue. The same observation applies to the tubes when filled with blood; in some parts of the specimen portions of the tube appear quite isolated, where they are concealed by the overlying matrix (*fig.* 150, *a a*), while in other parts the tubes are more or less distinctly visible through the intervening fibrous tissue (*b b*). In some parts transverse sections of the tubes are seen, and in other instances a considerable length of tube appears, uncovered by matrix; this tissue having been removed by the knife, while the tube itself has just escaped the section. In a subsequent part of this article reference will be made to certain pathological changes, as a consequence of which the tubes lose their epithelial lining and become more or less transparent; and in this condition, when they are packed in the meshes of the fibrous tissue, they have somewhat the appearance of separate globular or oval cells, and they have actually been described as such by an experienced microscopical observer.* This question will be fully considered hereafter, the object of the present brief allusion to it being to show the importance of studying the arrangement of a tissue which gives peculiar appearances to the parts with which it is connected, and a misapprehension of which may lead, as it has led, to serious practical errors.

Fig. 150.



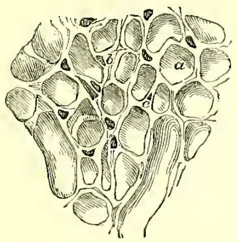
Convoluted tubes filled with blood, as seen when packed in the meshes of the matrix, magnified 200 diameters.

The large oval space represented in *fig.* 149, *c*, indicates the position of a Malpighian body; these bodies, as well as the tubes, being accurately fitted into meshes of the fibrous matrix. The arrangement of the fibrous tissue in the medullary cones is somewhat different from that of the cortical portion. The tissue in this part is more abundant, so that the tubes are separated by it to a greater distance than in the cortical portion of the kidney. The hardness and greater cohesion of the tissue of the medullary cones, as compared with that of the cortical portion, is in great part due to the more abundant fibrous matrix in which the tubes of this part are packed. A transverse section of the cones shows the matrix in the form of circular meshes surrounding the tubes, as in the cortical portion; but on a longitudinal section the meshes appear elongated, thus corresponding in form with the venous capillary meshes which occupy the substance of the fibrous tissue, and which in this part of the kidney are elongated in the direction of the tubes. There being no Malpighian bodies in the medullary cones, the larger meshes of the matrix which contain these bodies are not present in this part of the kidney. In order to ascertain the relation which the blood-vessels bear to the matrix, it is necessary to examine portions of a kidney which has been artificially injected, or one in which the vessels are filled with blood. It will then be seen, that while the tubes (*fig.* 151) accurately fill the meshes of the fibrous tissue, the capillary vessels (*b b* and *c*), forming a plexus which surrounds the tubes, are contained in the substance of the same tissue (*c c*). When the blood-vessels are

* On Subacute Inflammation of the Kidney, by John Simon, Esq. F. R. S., Med. Chir. Transactions, vol. xxx.

empty, they cannot be distinguished from the fibrous tissue in which they are imbedded; it

Fig. 151.



Section of the kidney, showing the relation of the tubes and blood-vessels to the fibrous matrix. *a*, portion of a tube; *b*, section of a blood-vessel; *c*, fibrous matrix. Magnified 100 diameters: from a specimen prepared by Mr. Bowman.

is only by the contrast of their colour when filled with blood, or with injection, that it can be ascertained that, in addition to the capillary vessels which surround the tubes, there is a connecting fibrous tissue, the office of which appears to be to support and retain in position the various complicated parts — tubes, Malpighian bodies, and blood-vessels — amongst which it is placed.*

Tubuli Uriniferi. — The tubuli uriniferi are so intimately connected with the Malpighian bodies, that it is not possible to give a complete description of one of these structures without an occasional reference to the other.

The general course and mode of division of the tubes, as well as their connexion with the Malpighian bodies, is best ascertained by the examination of specimens in which the tubes have been filled by injection; but our knowledge of the essential structure of the tubes, and particularly of their epithelial lining, would be very incomplete without a careful examination of uninjected specimens with a high magnifying power.

Mode of injecting the Tubes. — The tubes may be more or less completely injected in two modes: 1st, by a liquid thrown into them from the pelvis of the kidney; and 2dly, by the extravasation of materials forcibly injected into the blood-vessels of the Malpighian bodies. By the first mode the injected materials are made to enter the open mouths of the tubes at one extremity, and to pass towards the other, which, as will presently be shown, is a closed extremity; while by the second method the injection is admitted into the closed extremities of the tubes, whence it flows towards their open mouths, and so in some instances escapes into the pelvis of the kidney. By the last mode the tubes are often completely filled from one extremity to the other, while by the first method of injection they are generally very imperfectly filled, and this even when the air-pump has been used to aid the flow of the injection into the tubes. A consideration of the structure and relation of the tubes will show that this result is a necessary consequence of the anatomical disposition of the parts. Mr. Bowman remarks *, "To those who are acquainted with the practical difficulties of the injection of the ducts of glands in general, and especially of those which are very tortuous, the following considerations on this subject will probably appear conclusive. Even of the testis (where the tubes are far thicker and stronger in their coats, and much more capacious than in the kidney), there are not ten specimens that can be pronounced at all full in the museums of Europe: and there is no evidence that, even in the best of these, the injected material has reached the very extremities of the tubes. In the kidney, the tubes are exceedingly tortuous after leaving the Malpighian bodies, and only become straight, in most animals, in proceeding towards the excretory channel to discharge themselves. The way towards their orifices is so free in a natural state, that their fluid contents exert no distending force upon their walls. Accordingly their walls are exceedingly feeble; the basement membrane on which their strength mainly depends is very delicate, and easily torn. They are therefore incapable of offering much resistance to a fluid impelled into them from the pelvis, but burst easily if it be forcibly urged. But were the coats ten times as tough as they really are, injection could not penetrate far into their convoluted portion, unless pushed with much force; and this for two reasons: 1st, the fluid which the tubes already contain has no means of escape before the injection, since these canals end by blind extremities in the Malpighian bodies; 2dly, the layer of epithelium is, immediately after death, very prone to separate

* Mr. Toynbee, in a paper "On the Minute Structure of the Human Kidney,"[1] alludes to the presence of "parenchymal cells" in the kidney, to which he assigns an important function in preparing the blood for further changes in the tubuli, in which he says "cells of a character not very dissimilar are seen." He considers that "the relation in which the parenchymal cells stand to the nervous system is a subject of great interest;" and he arrives at the conclusion that the nervous filaments "end by becoming continuous with the parenchyma of the organ precisely as he has observed those in the tail of the tadpole to become directly continuous with the radiating fibres of stellated corpuscles, and the filaments from the corpuscles to communicate with each other." He further states that in certain diseased states of the kidney, "the parenchymatous cells will be found not merely increased in size, but adipose depositions will be visible throughout them." The account which Mr. Toynbee gives of these so-called parenchymal cells is not such as will enable me to state with confidence to what particular appearances his description of them applies; but as I have never been able to satisfy myself of the existence of any such cells as those referred to by him, and as I am not aware that they have been recognized by those anatomists who have most carefully studied the structure of the kidney, I cannot confirm Mr. Toynbee's observations as to their function, their connexion with the nerves, or the pathological changes which they undergo.

[1] Med. Chir. Trans., vol. xxix.

* Philosophical Transactions, 1842.

from the basement membrane which it lines, and to fall into and block up its narrow channel." It consequently happens that, in face of mechanical obstacles such as those above mentioned, the force employed to inject the tubes sooner or later bursts their coats ere their extremities have been reached.*

Course and Termination of the Tubes.—Tracing the tubes from the apex of a medullary cone, on the surface of which their open mouths may be seen, we find them taking a straight course through the pyramid, branching dichotomously and diverging as they proceed (*fig.* 143). After reaching the base of the pyramid, their course through the cortical portion is very various; many tubes immediately take a very tortuous course, some of them bending down into the inter-pyramidal portions of the cortical substance, while those near the centre of the pyramid pass onwards in a mass and in a straight line towards the surface, the tubes on the sides of the bundle in their progress passing off successively in a tortuous course through the cortical substance, so that only a few of the central tubes in each bundle retain their straight course quite up to the surface of the kidney; these finally turn backwards, making many convolutions in the cortical substance. After leaving the medullary cones, the branching of the tubes, except in very rare instances, appears to cease; occasionally two tubes in the cortical substance unite in passing towards the cones; and I once saw this occur at a very short distance below the Malpighian bodies, so that two short tubes, each with a Malpighian body at its extremity, united into one common tube. Some distinguished anatomists have maintained that the tubes, after dividing in the cortical substance, reunite in a plexiform manner, and they have described this as their natural mode of termination. This opinion is in all probability founded on deceptive appearances, such as must often have presented themselves when the means of observation were less perfect than they now are, and which even at this time are but of too frequent occurrence. It appears to be a general fact that *the tubes divide in their course from the apices of the medullary cones towards their opposite terminations, but they never reunite while passing in this direction.* Other anatomists have considered the tubes to terminate in free blind extremities unconnected with the Malpighian bodies; and they have based their opinion on the appearances of injected specimens as well as on those of recent ones. With reference to this question Mr. Bowman* remarks, "As the injection always stops short of the real extremities of the tubes, it must necessarily show apparent free extremities—and others may be produced by the section requisite for the examination of the part. As for the false appearances presented by recent specimens, they are obviously referable to the sudden bending down of a tube behind the part turned to the observer. In a mass composed of convolutions, many such must continually occur; and their real nature may be easily determined by the use of a high power and varying focus." In addition to the sources of fallacy thus alluded to by Mr. Bowman, there is another, to which I have already referred† in describing the fibrous matrix in which the tubes are packed. To an inexperienced observer, few appearances could be more deceptive than the apparent abrupt terminations of the tubes, as these are seen in the spaces formed by the surrounding tissue, here visible in the meshes of the network, and there suddenly concealed as they pass beneath the fibrous tissue.

The manner in which the tubes actually terminate is by becoming continuous with the Malpighian bodies. This fact, which can be demonstrated in many of the tubes, is a matter of fair inference and of moral certainty in the case of every tube. The proofs of this fact, and the precise mode of continuity, we shall presently proceed to examine.

Structure of the Tubes.—The uriniferous tubes contain the two structures which usually compose the mucous tissue, viz. the *basement membrane* and the *epithelium.*‡

The basement membrane is a thin transparent homogeneous lamina, simple and entire, without any aperture or appearance of structure. It forms the parenchymal wall of the uriniferous tubes; gives them their form, size, and stability; is in relation, on the one hand, with the vascular system of the organ and the investing fibrous matrix, and on the other, with the epithelial lining of the tubes. The epithelium adheres to the inner surface of the membrane by organic union: it sometimes separates readily after maceration in water, and in some forms of chronic inflammation of

* In opposition to the opinion of Mr. Bowman, supported as it is by facts and arguments which, to most practical anatomists who are acquainted with the structure and relations of the tubes and Malpighian bodies, will appear quite conclusive, Mr. Toynbee states that the possibility of injecting the entire length of the tubes, and even the Malpighian capsules from the pelvis of the kidney, is abundantly proved by many of his own specimens, in which the Malpighian bodies are in this way distended, and that without any extravasation into the vascular tissues. If the account which Mr. Bowman has given of the connexion of the tubes with the Malpighian bodies be a correct one, it is clearly impossible that the tubes, long, tortuous, closed at their extremities, and always containing more or less liquid, can be completely injected from the pelvis of the kidney, unless the rupture of the tube or of the Malpighian capsule allows the liquid contents of the tube to give place to the injected material. Certainly the Malpighian capsules cannot possibly be injected from the tubes so long as the tubes and the capsules remain entire. If, therefore, Mr. Toynbee is correct in his observation on this point, the explanation of the fact must, as I think, be that which I have given. His account of the Malpighian bodies (Med. Chir. Transactions, vol. xxix. p. 311), and of their relation to the tubes, so far as I can comprehend the description given, appears to be incorrect; and his diagrams of these bodies (Plate 8, loc. cit.) represent appearances such as I have never observed in the course of my own examinations.

* Loc. cit.

† *Vide antè*, p. 239.

‡ *Vide* art. Mucous Membrane.

the kidney it frequently happens that the epithelial lining of many of the tubes is entirely removed, or only a few particles of epithelium remain scattered over the inner surface of the membrane. "It sometimes happens, that when the epithelium may seem to be altogether detached, the basement membrane retains, scattered evenly over its surface and at some distance apart, a number of roundish marks, of the size and aspect of the nuclei of epithelium particles. These are most probably the early condition of the new or advancing series of these particles." * The basement membrane is united externally to the capillary venous plexus and the investing fibrous matrix; there is probably some organic connexion between these tissues, which allows of the free transudation of materials from the blood-vessels through the basement membrane to the epithelial cells. When a tube deprived of its epithelium is detached from the surrounding tissue, the basement membrane is readily thrown into folds and wrinkles, and appears to possess a considerable amount of elasticity. The thickness of this membrane, according to Mr. Bowman, does not exceed $\frac{1}{20000}$th of an English inch. In certain diseased states of the kidney its thickness is much increased, and simultaneously the cavity of the tube becomes dilated so as greatly to exceed its normal diameter, thus constituting the serous cysts which are so frequently observed in the kidney.

The basement membrane of the tubes is continuous on the one hand with the capsule of the Malpighian bodies, and on the other through the straight tubes of the pyramids with the basement layer of the mucous membrane which lines the pelvis of the kidney.

The mean diameter of the tubes is about $\frac{1}{480}$ inch. The entire diameter of the convoluted tubes in the cortical portion somewhat exceeds that of the straight tubes in the pyramids, although the cavity of the latter is greater than that of the former. The latter fact resulting, as will be seen hereafter, from the difference in the character of the epithelium in these portions of the tubes.

After the brief allusion just now made to the epithelium of the tube and its relation to the basement membrane, it will be more convenient to postpone for the present the particular consideration of this important structure, and to proceed to the examination of the Malpighian bodies. We shall then revert to the epithelium, and we shall find that the varying characters which it presents in different parts of the organ are of the greatest interest and importance in connection with the physiology of the renal secretion, as well as on account of the assistance which they afford in the interpretation of the pathological changes to which the kidney is liable.

Malpighian Bodies. — The Malpighian bodies have been objects of much interest since their discovery by the distinguished anatomist whose name they bear. Malpighi † ascertained that these bodies, which he calls internal glands, could be readily injected from the arteries, to the branches of which they are appended. He could not succeed in injecting them from the veins, in consequence, as he believed, of valves in these vessels preventing the passage of the injected material in a backward direction; he, however, considers it a rational inference, that the venous radicles commence in these bodies. Malpighi further endeavoured to demonstrate the connection which he believed to exist between these bodies and the urinary tubes. He made unsuccessful attempts to inject the tubes from the arteries and from the veins: and, finally, he experimented on a living dog, by tying the renal veins and the ureters. On examination of the kidneys after death, there were some appearances of the renal glandules (the Malpighian bodies) and the tubes being connected and continuous; but he confesses that his opinion on this point was derived rather from analogy than from ocular demonstration, his idea being that the urinary constituents were separated from the arteries of the Malpighian bodies, and that the tubes were the excretory ducts of these glands.

* Art. Mucous Membrane.

† Exercitatio Anatom. de Renibus.

Ruysch * appears to have been the first to show that the urinary tubes may be injected through the arteries of the Malpighian bodies, and he supposed that the arteries become directly continuous with the urinary tubes. Boerhaave † described the cortical portion of the kidney as being composed partly of glandular Malpighian bodies, and partly of blood-vessels, which form a plexus without being connected with the Malpighian bodies; he also inferred the existence of two kinds of excretory ducts, the one kind being connected with the Malpighian bodies, while the others are directly continuous with the blood-vessels; and he supposed that the more watery portion of the urine is excreted by the latter, while the denser portion prepared in the Malpighian bodies is carried off by the first-mentioned ducts. Bertin ‡ agrees for the most part with Boerhaave as to the anatomy of the kidney, but he assigns to the Malpighian bodies the office of secreting the more liquid portion of the urine, and supposes that the denser parts are separated by those blood-vessels which, as he believed, are not connected with the Malpighian bodies, but are directly continuous with the urinary tubes.

Schumlansky §, while he confesses the great difficulty of arriving at an accurate knowledge of the structure of the Malpighian bodies and their connexion with the urinary tubes, appears to have had as definite an idea of these parts as it was possible to arrive at with the imperfect means of observation which he possessed. He describes the Malpighian bodies as consisting of a glomerulus of vessels, connected on the one side with the arteries, and

* Thesaurus Anatom.

† Institut. Medic.

‡ Mem. de l'Acad. Roy. des Sciences, 1744 Op. cit.

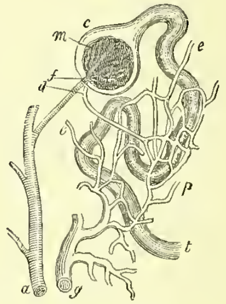
§ De Structurâ Renum. Argent. 1788.

on the other with the veins, and invested by a cellular tissue in a manner which he does not very clearly explain. He believes that there is a close connexion between the Malpighian bodies and the tubes, as manifested by the fact, that the tubes may be filled by a forcible injection of the Malpighian bodies through the arteries: further confirmation of this fact being afforded by the occasional passage of blood and other materials through the same channels, and the tubes being found filled with blood after death. With respect to the last observation, which he quotes from Bertin, he appears to have some doubt, and suggests that the vessels containing the blood may have been blood-vessels, and not uriniferous tubes.

Since the time of Schumlansky, whose work above quoted was published in the year 1788, scarcely any addition was made to our knowledge of the structure of the Malpighian bodies until the publication of Mr. Bowman's paper*, already so often referred to. In some respects, indeed, the description given of the Malpighian bodies by the best anatomists immediately before the appearance of Mr. Bowman's paper, is less accurate than that of Schumlansky, and some of his predecessors. Thus, Müller† denied, in the most positive manner, the existence of any connexion between the Malpighian bodies and the tubes, and the possibility of injecting the latter from the former. Professor Müller has since ‡ acknowledged and confirmed the accuracy of Mr. Bowman's observations, which I shall now proceed to detail as much as possible in his own words, because it would be impossible to depart much from the language of his paper without incurring a risk of losing something of the clearness which characterises the original.

The Malpighian bodies consist of a rounded mass of minute blood-vessels, invested by a cyst or capsule. The capsule was first particularly described by Müller, who believed it to be closed on all sides except at one point, where it is perforated by the blood-vessels. He accurately described the arterial branch as passing into the cavity of the capsule, where it gives off tortuous branches, which form arches, and then return to the point at which the artery enters, so that the tuft of vessels is free in the cavity of its investing capsule, being connected with the latter only at one point. Mr. Bowman, observing that the capsule of the Malpighian bodies had an appearance precisely similar to that of the basement membrane of the tubes, and seeing these similar tissues in such close proximity, was led to suspect that the capsule was in fact the basement membrane of the tubes expanded over the vessels, and after some time he succeeded in obtaining an unequivocal view of their continuity. This important result was arrived at after the use of the *double injection*. After the injection of some kidneys through the artery by this method, it was found that the injected material had in many instances burst through the tuft of Malpighian vessels, and being extravasated into the capsule, had passed off along the tube. (*Figs*. 153. 3. 156, 157.) Mr. Bowman afterwards made numerous injections of the human kidney, and of that of many of the lower animals, and in all, without exception, he met with the same disposition. He also examined thin slices of the recent organ with high powers of the microscope, and in this manner fully corroborated the evidence furnished by injections. This mode of examination likewise led Mr. Bowman to the very interesting discovery of ciliary motion within the orifice of the tube and the contiguous portion of the Malpighian capsule. According to the observations of Mr. Bowman, the circulation through the kidney may be stated to be as follows: — "All the blood of the renal artery (with the exception of a small quantity distributed to the capsule, surrounding fat, and the coats of the larger vessels,) enters the capillary tufts of the Malpighian bodies; thence it passes into the capillary plexus surrounding the uriniferous tubes, and it finally leaves the organ through the branches of the renal vein." (*Fig*. 152.)

Fig. 152.



Plan of the renal circulation in Mammalia. (*After Bowman.*)

The relative proportions and the character of the several parts are accurately copied from preparations of the human kidney. The artery, *a*, is seen giving a terminal twig, *f*, to a Malpighian tuft, *m*, from which emerges the efferent (or portal) vessel, *d*. Other efferent vessels are seen, *e*, *e*, *e*. All these enter the plexus of capillaries, *p*, surrounding the uriniferous tube, *t*. From this plexus the emulgent vein, *g*, springs. Supposed to be magnified about forty diameters.

Following it in this course, I shall now give Mr. Bowman's description of the vascular apparatus, and the nature of its connexion with the tubes. I shall also refer to some observations which have been made since the publication of Mr. Bowman's paper, premising that Mr. Bowman's description is so singularly accurate that it scarcely requires or admits of any, even the slightest, addition or modification, with reference to those particulars which it embraces.

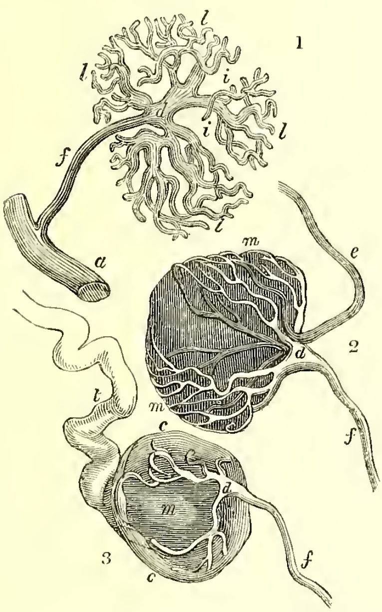
* On the Structure and Use of the Malpighian Bodies of the Kidney. Philos. Trans. part i. 1842.

† J. Müller, de Glandularum Secernentium Structurâ Penitiori. Lips. 1830.

‡ Untersuchungen über die Eingeweide der Fische. J. Müller, Berlin, 1845.

With the inconsiderable exceptions above mentioned, the terminal twigs of the artery correspond in number with the Malpighian bodies. Arrived here, the twig, which is usually of considerable length, although occasionally very short, perforates the capsule, and, dilating suddenly, breaks up into two, three, four, or even eight branches, which diverge in all directions like petals from the stalk of a flower, and usually run in a more or less tortuous manner, subdividing again once or twice as they advance over the surface of the ball they are about to form. (*Fig.* 153.)

Fig. 153.



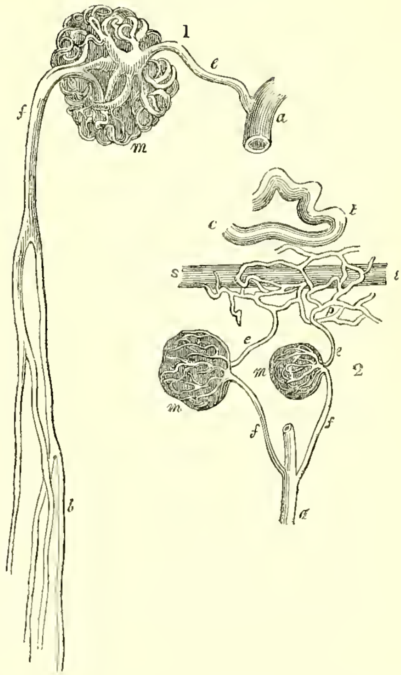
1. Malpighian tuft. — Horse. The injection has penetrated only to the capillaries. *a*, the artery; *f*, one of its terminal twigs (or the afferent vessel of the Malpighian body); *d*, the dilatation and mode of breaking up of the terminal twig after entering the capsule; the division of the tuft into lobes, *l, l, l, l*, is well seen; *i, i*, intervals between the lobes. Magnified about eighty diameters.

2. Malpighian tuft. — Horse. The injection has penetrated through the tuft, and has filled the afferent vessel. *f*, the afferent vessel; *d*, its dilatation and mode of division; *m, m*, Malpighian capillaries; *e*, efferent vessel springing from them, and leaving the capsule between two primary branches of the afferent vessel. Magnified about eighty diameters.

3. Malpighian body. — Horse. The injection, after filling the primary branches of the afferent vessel, has burst into the capsule, and passed off along the tube. It has not filled the tuft of capillaries, which consequently are not seen, nor has it spread within the capsule over the whole surface of the tuft. *f*, the afferent vessel; *d*, its dilatation and mode of subdivision; *c, c*, the outline of the distended capsule; *t*, the tube passing from it; *m*, situation of the uninjected Malpighian tuft. Magnified about seventy diameters. (*After Bowman.*)

The vessels resulting from these subdivisions are capillary in size, and consist of a simple, homogeneous, and transparent membrane. They dip into its interior at different points, and, after further twisting, reunite into a single small vessel (*fig.* 154. 1.), which varies in its size, being generally smaller, but in some situations larger, than the terminal twig of the artery. This vessel emerges between two of the primary divisions of the terminal twig of the artery, perforating the capsule close to the vessel, and, like it, adhering to the membrane as it passes through. It then enters the capillary plexus, which surrounds the tortuous uriniferous tubes. (*Fig.* 154. 2. and 155.) The

Fig. 154.



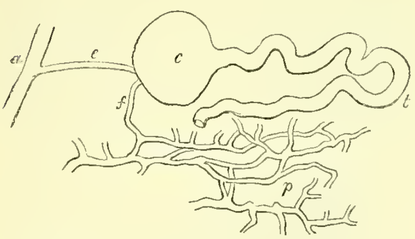
1. Malpighian body, &c., from the horse. Malpighian tuft, from near the base of one of the medullary cones, injected without extravasation, and showing the efferent vein branching like an artery, as it runs into the medullary cone. *a*, arterial branch; *e*, the afferent vessel; *m*, the Malpighian tuft; *f*, the efferent vessel; *b*, its branches entering the medullary cone. Magnified about seventy diameters. (*After Bowman.*)

2. Malpighian bodies, &c., from the horse. The injection has passed, as in *fig.* 155., but without rupture of the Malpighian tuft. *a*, branch of the artery; *f, f*, afferent vessels; *m, m*, Malpighian tufts; *e, e*, efferent vessels; *p*, plexus surrounding the tubes; *s t*, straight tube in cortical substance; *c t*, convoluted tube in ditto. Magnified about thirty diameters.

tuft of vessels thus formed is a compact ball, the several parts of which are held together solely by their mutual interlacement, for there is no other tissue admitted into the capsule besides blood-vessels. It is subdivided into as many lobes as there are primary branches of the terminal twig or efferent vessel, and these lobes do not communicate, except at the

root of the tuft. There are, therefore, deep clefts between them, which open when the lobes are not greatly distended with injection or blood. (*Fig.* 153, 1.) The surface of

Fig. 155.



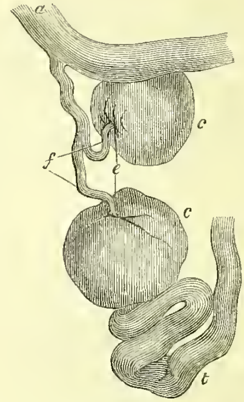
Malpighian body, tube, &c., from the horse. The injection has penetrated from the artery through the Malpighian tuft into the plexus surrounding the tubes. It has then ruptured the vessels of the tuft, filled the capsule, and passed off along the tube. *a*, arterial branch; *e*, afferent vessel; *c*, capsule distended; *t*, tube; *f*, efferent vessel; *p*, plexus of capillaries, surrounding other tubes not injected. Magnified about thirty diameters. (*After Bowman.*)

the tuft is everywhere unattached and free, and continuous with the opposed surfaces of the lobes. The whole circumference of every vessel composing the tuft is also free, and lies loose in the cavity of the capsule. These circumstances cannot be seen in specimens gorged with injection, but only by careful examination of recent specimens with a power of 200 or 600 diameters.

The vessels are so perfectly bare, that in no other situation in the body do the capillaries admit of being so satisfactorily studied. It is only where the tuft is large, as in man and in the horse, that its lobulated character can be always discerned. Where the number of primary subdivisions of the afferent vessel is smaller, the detection of lobes is less easy; they may often be seen, however, in the frog. In Birds and Reptiles the afferent vessel seldom divides; but dilates instead into a pouch-like cavity, which, after taking two or three coils, contracts again, and becomes the efferent vessel. There are of course no lobes; but the surface of the whole dilated part is free.

The basement membrane of the uriniferous tube, expanded over the Malpighian tuft to form its capsule, is a simple homogeneous and transparent membrane, in which no structure can be discovered. *It is perforated*, as before stated, *by the afferent and efferent vessels, and is certainly not reflected over them.* They are united to it at their point of transit, but in what precise manner Mr. Bowman has not been able to determine. It appears probable that the membrane is reflected to a slight extent upon the afferent and efferent vessels, and that thus the union is effected. The appearance of bulging presented by the distended capsule round the entrance of the afferent vessels in *fig.* 156. seems to indicate that the membrane is slightly reflected inwards upon the trunks of the vessels, if this term can be correctly applied to such minute

Fig. 156.



Two Malpighian bodies injected from the human subject. The tufts are burst and the fluid has escaped into the capsule. In one case it has passed also along the tube, the extreme tortuosity of which at its commencement is well seen. *a*, arterial branch; *f*, terminal twigs; *c*, *c*, Malpighian capsules distended; *e*, the depression often seen in such cases, at the point where the afferent and efferent vessels pass: the latter are not here injected; *t*, the tube. Magnified about ninety diameters. (*After Bowman.*)

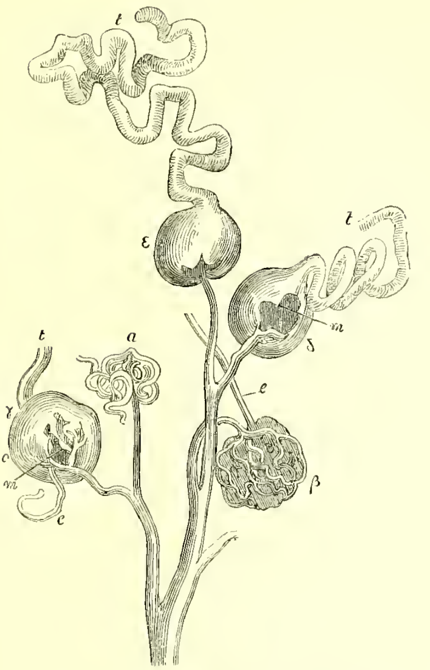
vessels as the afferent and efferent vessels of the Malpighian bodies. Opposite to the point where the vessels perforate the capsule, is the orifice of the tube, the cavity of which is continuous with that of the capsule, generally by a constricted neck. Mr. Bowman has specimens prepared with the double injection, showing this continuity in Mammalia, Birds, Reptiles, and Fish. (*fig.* 157.)

A more satisfactory proof of the direct continuity of the cavity of the tube with that of the Malpighian capsule is afforded by a clear view of the whole of the textures magnified 200 or 300 diameters. The capsule may thus be seen to pass off into the basement membrane of the tube as the body of a Florence flask into its neck (*figs.* 158. and 159.).

The basement membrane of the tube is lined by a nucleated epithelium of a finely granular opaque aspect, while the neck of the tube and the contiguous portion of the capsule are covered by a layer of cells much more transparent, and clothed with vibratile cilia. The epithelium appears to be continued in many cases over the whole inner surface of the capsule, while in other instances it is impossible to detect the slightest appearance of it over more than a third of the capsule. When fairly within the capsule the cilia cease, and the epithelium beyond is of excessive delicacy and translucence. Its particles are seldom nucleated, and appear liable to swell by the application of water to the specimen. The cavity existing in the natural state be-

tween the capsule and the vascular tuft, is filled by fluid, in which the vessels are bathed, and which is continually being impelled from the capsule into the tube by the lashing movement of the cilia.

Fig. 157.

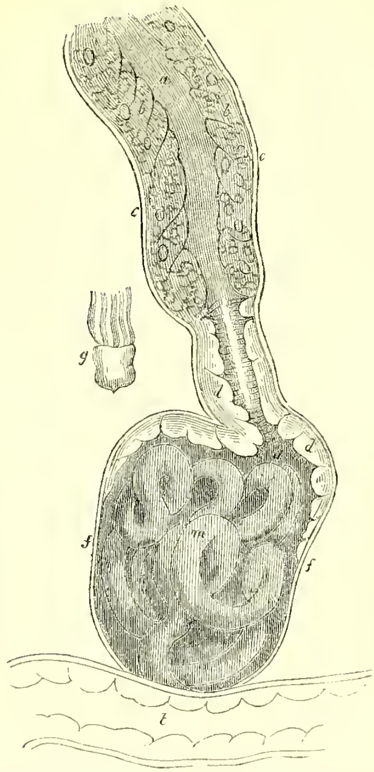


This specimen has been chosen because it exhibits the termination of a considerable arterial branch wholly in Malpighian tufts, and because the several Malpighian bodies injected show different appearances of a very instructive kind. *a*, arterial branch with its terminal twigs; at *a* the injection has only partially filled the tuft, at *β* it has entirely filled it, and has also passed out along the efferent vessel, *e*, without any extravasation, at *γ* it has burst into the capsule and escaped along the tube *t*, but has also filled the efferent vessel *e*, at *δ* and *ε* it has been extravasated and passed along the tube, at *m* and *m*, the injection on escaping into the capsule has not spread over the whole tuft. Magnified about forty-five diameters. From the human subject. (*After Bowman.*)

This very interesting phenomenon of ciliary motion in the neck of the tube and in the Malpighian capsule was discovered by Mr. Bowman in the frog; and at the time when his paper was published he had not observed it in any other animal. Mr. Simon* afterwards observed it, as he says, "at the origin of each uriniferous tubule in the kidneys of various other reptiles, and also with perfect distinctness in the skate." Bidder† has since observed the same phenomenon in the triton; Kölliker‡ has described it in the embryo lizard; and I have seen it in the common snake.

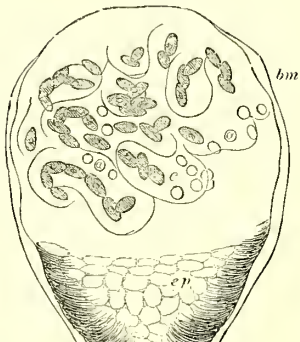
* A Physiological Essay on the Thymus Gland, by John Simon, F.R.S.
† Müller's Archiv. 1845.
‡ Müller's Archiv. 1845.

Fig. 158.



From the frog; viewed by transmitted light. Shows the continuity of the Malpighian capsule with the tube, the change in the character of the epithelium, and the vascular tuft. *c*, basement membrane of the tube; *b*, epithelium of the tube; *a*, cavity of the tube; *f f*, basement membrane of the capsule; *d*, epithelium of the neck of the tube and of the neighbouring part of the capsule, this epithelium is covered with cilia, which were seen in active motion eight hours after death; *g*, detached epithelial particle, more highly magnified, showing the relative length of the cilia, as they appeared in this specimen. The capillaries, *m*, lie bare in the cavity of the capsule, having entered it near *t*, where the view is obscured by another tube. Magnified about 320 diameters. (*After Bowman.*)

Fig. 159.



Malpighian body from the newt (Triton). This

specimen shows the abrupt termination of the ciliated epithelium, *e p*, within the capsule, *a a*, Some rounded particles, which are sometimes seen in considerable numbers, either on the surface or in the wall of the vessels *c*. The basement membrane of the capsule, *b m*, beyond the termination of the ciliated epithelium appears quite naked. Magnified 200 diameters.

I am not aware that ciliary motion has been detected in the kidneys of Mammalia or Birds. I shall presently show that in certain fishes and reptiles the cilia are not confined to the situation in which they were first discovered by Mr. Bowman; but that they exist throughout the greater part, if not the whole length, of the uriniferous tubes.

It appears desirable to allude here to some observations which have been made since the publication of Mr. Bowman's paper, and to inquire how far certain statements which have been opposed to his account of the Malpighian bodies are worthy of consideration. It is not my intention to occupy time and space, by giving a history of all the contradictory opinions which this subject has elicited. It may be fairly inferred that inability to detect ciliary motion within the Malpighian capsule, or to verify any observation in reference to which several competent authorities are agreed, is the result of some defect in the microscope employed, or in the eye or mind of the observer.

Objections have been made to two parts of Mr. Bowman's description; first, to his account of the relation which the Malpighian capsule bears to the basement membrane of the tube and to the blood-vessels; and, secondly, to his statement that the Malpighian capillaries lie uncovered within the capsule.

Bidder* made his observations on the kidney of the male triton (Triton tæniatus). The anterior part of the kidney of this animal is exceedingly well adapted for the investigation in question, since it is very thin and transparent, and is thus fitted for microscopical examination without further artificial preparation by tearing or other means. Bidder believes that the vessels do not perforate the capsule to enter its cavity, as described by Mr. Bowman; but he considers the basement membrane to be introverted so as to form a covering for the vessels and a complete partition of a semilunar form between the cavity of the tube and that of the Malpighian capsule. I have examined the kidney of the triton with great care, and have satisfied myself that Mr. Bowman's account of the perforation of the capsule by the vessels is strictly correct, and that there is no partition, but, on the contrary, a free communication, between the cavity of the capsule and the orifice of the tube. When the vessels are distended with blood, they almost fill the capsule; on the contrary, when they are empty, they shrink into a small compass. I have examined them under both conditions, and could never detect any appearance of a membrane reflected over them. The free communication between the cavity of the capsule and the orifice of the tube is sufficiently shown by two phenomena which I have repeatedly witnessed: first, when the cilia are in action, the liquid filling that part of the capsule which is unoccupied by the vessels is freely propelled from the cavity of the capsule into the tube; and, secondly, when water is added to the specimen, loose particles of epithelium from the tube are often driven into the capsule, until they fill that part of its cavity which is not occupied by the collapsed blood-vessels.

* Müller's Archiv. 1845.

Dr. Gerlach* describes and figures the Malpighian capsule as being not a blind termination of the uriniferous duct, but a lateral diverticulum of the same structureless basement membrane which forms the duct; and he believes that the capsule communicates with the duct by means of a short neck. It is not impossible that there may, in some rare instances, be a diverticulum from a tube as represented by Gerlach; but as I have never yet seen such a mode of connexion between a tube and a capsule, and as I have seen numberless instances of tubes terminating directly in the dilatation which constitutes the Malpighian capsule, I do not hesitate to declare my decided conviction that Mr. Bowman has correctly described the structures in question.†

With reference to the second point above alluded to, namely, to Mr. Bowman's statement that the Malpighian capillaries lie uncovered within the capsule, the observations of Gerlach deserve more consideration. He states that when the Malpighian capillary network is examined after the capsule has been entirely detached from it, it may be seen in its whole extent covered by a thick layer of nucleated cells, which are continued from the inner wall of the capsule upon the Malpighian vessels; so that the latter lie introverted within a layer of cells like the intestine within the peritonæum (*fig.* 160.); and he supposes that the secreting structure of the Malpighian bodies differs from the ordinary structure of glands

* Müller's Archiv. 1845.

† Dr. Gerlach's opinion of the manner in which the tubes are connected with the Malpighian capsules, is founded upon appearances which he observed after injecting the urinary tubules from the pelvis of the kidney. He believes that in this manner he succeeded in filling the Malpighian capsules as well as the tubes, and that, too, as he says, after he had failed in filling these parts by injection of the Malpighian vessels from the artery in the manner before described. (*Vide antè*, p. 241.) On a careful consideration of the drawings by which Dr. Gerlach's paper is illustrated, there seems reason to believe that the appearances which he describes as Malpighian bodies may result from a sudden bulging of the tubes produced by forcible distension with the rejected material. (See Müller's Archiv., 1845, plate 13.) It cannot be a matter of surprise that a forcible injection of the tubes from the pelvis should give rise to unnatural appearances in these structures; whereas a slow infiltration of injection from the ruptured Malpighian vessels, or an equally slow extravasation of blood during life, while it fills the capsules and the tubes, leaves these parts as nearly as possible in their normal condition, and affords the most satisfactory evidence as to the nature of their connexion with each other.

only in the absence of the basement membrane between the vessels and secreting cells.

Dr. Gerlach's figure (*fig.* 160.) exhibits an

Fig. 160.

Malpighian tuft of capillaries covered with small transparent nucleated cells. (*After Gerlach.*)

appearance which every one must have seen in the tuft of vessels extended from the capsule, but which fails to establish the existence of this epithelial investment of the tuft; for at the border of the figure the wall of the capillaries is seen actually bare, as described by Mr. Bowman. The fact, however, seems to be, that there do exist, here and there, upon the outside of the capillaries of the tuft, nucleated particles, of an extremely delicate nature, the nuclei sometimes lying isolated in the fork of two vessels, and the substance of the cell not expanding into a continuous covering of the whole tuft. It is possible that these nucleated particles may be rather the nuclei belonging to the capillary wall, than a modified representation of the epithelium of the tube. It is at least certain that they lie sparingly upon the individual vessels of the tuft, and do not form a membranous investment of it as a whole. Mr. Bowman showed me these particles, as I have now described them, some years ago. Their existence does not affect the substantial accuracy of his account of the anatomy of the tuft, nor his view of its special share in the secretion of urine.

Having thus briefly alluded to certain parts of Mr. Bowman's description of the Malpighian bodies, the correctness of which has been questioned, and having shown, as I hope, that only in one minute part of his clear and accurate account of their structure is any modification required, we may proceed to trace the blood-vessels in their course from the Malpighian bodies.

The blood, leaving theMalpighian tufts, is conveyed by their efferent vessels to the great renal reservoir, the capillary plexus surrounding the uriniferous tubes (*figs.* 152. 154. and 155.). The vessels lie in the interstices of the tubes, and everywhere anastomose freely, so that throughout the whole organ they constitute one continuous network, lying on the outside of the tubes, in the substance of the matrix, and in contact with the basement membrane. This plexus is intermediate between the efferent vessels of the Malpighian bodies and the veins.

The efferent vessels of the Malpighian bodies are always solitary, and never inosculate with one another: each one is an isolated channel between its Malpighian tuft and the plexus surrounding the tubes. They are formed by the union of the capillary vessels of the tuft, and emerge from its interior in the manner already explained. After a course of variable length they open into the plexus. Their size is various. In general they are smaller than the terminal twig of the artery, and scarcely, if at all, larger than the vessels of the plexus into which they discharge themselves. But where the Malpighian tuft is larger, the efferent vessel is usually large also, and divides into branches before entering the plexus. This is eminently the case with those situated near the base of the medullary cones, where the medullary and cortical portions of the organ seem to blend. The efferent vessels from these large Malpighian bodies are often three or four times the diameter of those of the plexus, and take a course towards the pelvis of the kidney between the uriniferous tubes (*fig.* 154. 1.). They were formerly mistaken for tubes. They branch again and again in the manner of arteries, and form the plexus with long meshes, which invests this part of the tubes. Some of the veins springing from this plexus form the well-known network on the nipple-shaped extremities of the cones, around the orifices; and thence take, with the remainder, a backward course, likewise parallel to the tubes, to empty themselves into various branches that lie about the bases of the cones. The arrangement of the venous radicles on the cortex and on the surface of the kidney has been already described (*fig.* 145). The veins from the capsule and surrounding fat join the renal vein in some part of its course. It is probable that the capillaries of the vasa vasorum, within the substance of the organ, pour their blood into the capillary plexus surrounding the tubes, as those of the hepatic artery do into the portal hepatic plexus of the lobules of the liver.

Thus, there are in the kidney *two perfectly distinct systems of capillary vessels*, through both of which the blood passes in its course from the arteries into the veins: the first, that inserted into the dilated extremities of the uriniferous tubes, and in immediate connection with the arteries; the second, that enveloping the convolutions of the tubes, and communicating directly with the veins. The former, which may be called the Malpighian capillary system, is made up of as many parts as there are Malpighian bodies. These parts are entirely isolated from one another; and as there is no inosculation between the arterial branches supplying them, the blood enters each in a direct stream from the main trunk. Each separate part also of this system has but one afferent and one efferent channel, and both of these are exceedingly small, compared with the united capacity of the capillary tuft. The artery in dividing dilates; then follow branches which often exceed it in size, and which gradually break up into the finest. The efferent vessel does not usually even equal the afferent, and in size is often itself a capillary. Hence would arise a greater retard-

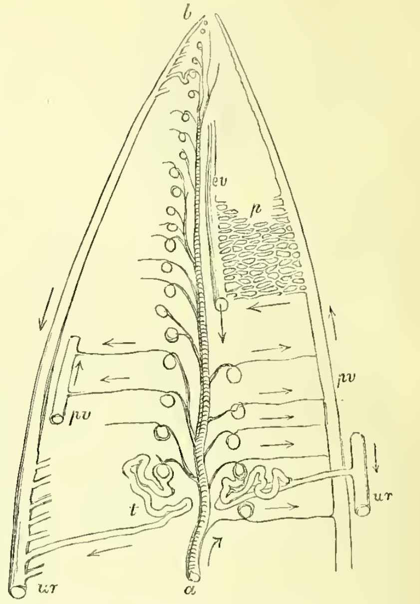
ation of blood in the tuft than occurs probably in any other part of the vascular system; a delay that must be increased by the tortuosity of the channels to be traversed.

The other system of capillaries, or that surrounding the uriniferous tubes, corresponds, in every important respect, with that investing the secreting canals of other glands. Its vessels anastomose with the utmost freedom on every side, and lie on the deep surface of the membrane that furnishes the secretion.

Mr. Bowman has applied the term "*portal system of the kidney*" to the series of vessels connecting these two, on account of the close analogy it seems to bear to the vena porta, intervening, like it, between two capillary networks, the first of which answers to that in which the vena porta originates, and the second to that in which the vena porta terminates. The capillary plexus surrounding the tubes differs, therefore, from that of other glands, and agrees with that of the liver, in its receiving blood that has previously traversed another system of capillary vessels.

The correctness of the analogy which Mr. Bowman has drawn between the circulation of the kidney and that of the liver is very beautifully shown by his observations on the kidney of the boa-constrictor, an animal which may be regarded as the type of those in which, besides the renal artery, the kidney receives a portal vein derived from the hinder part of the body.* Mr. Bowman thus describes the organ in question: — "The kidney of the boa, being composed of isolated lobes of a compressed reniform shape, displays all the points of its structure in peculiar simplicity and beauty. At what may be termed the hilum of each lobe, the branches of the vena porta and duct separate from those of the renal artery and emulgent vein; the two former spreading side by side, in a fan-like form, over the opposite surfaces of the lobe, while the two latter enter its substance and radiate together in a plane midway between these surfaces. The lobe is made up of the ramifications of these four sets of vessels, in the following mode (*fig.* 161.). Each *duct*, as it runs over the surface, sends down a series of branches which penetrate in a pretty direct manner towards the central plane. Arrived there, they curl back, and take a more or less retrograde course towards the surface, and, finally, becoming more convoluted, terminate in the Malpighian bodies, which are all situated in a layer at some distance within the lobe, parallel to the central plane, and nearer to it than to the surface. The ducts never anastomose. The *artery* subdivides into extremely minute twigs, no larger than capillaries, which diverge on either hand and enter the Malpighian bodies. The efferent vessels are of the same size as the afferent, and, on emerging, take a direct course to the surface of the lobe, and join the branches of the vena porta there spread out. The branches of the *portal vein* on the surface send inwards a very numerous series of twigs

Fig. 161.



Plan of the arrangement of the elements of the kidney, in the boa constrictor, by Mr. Bowman.

a, arterial branch in the centre of the lobule, sending afferent twigs to the Malpighian bodies on each side. The efferent vessels are seen running to the branches of the portal vein, *p v*, *p v*, on the surfaces of the lobule. The plexus surrounding the tubes is seen at *p*, running from the portal vein to the emulgent vein, *e v*, which lies in company with the artery in the centre of the lobule. The uriniferous tube, *t*, is seen commencing in the M. body, and passing to the branch of the ureter, *u r*, *u r*, at the surface of the lobule where it accompanies the portal vein. The M. bodies are seen diminishing in size, as the tubes become shorter towards the thin edge of the lobule *b*.

of nearly uniform capacity, and only a little larger than the vessels of the *capillary plexus*, in which they almost immediately terminate. This is the plexus surrounding the uriniferous tubes. It extends from the surface to the central plane of the lobe, and there ends in the branches of the *emulgent vein*."

"Thus the efferent vessels of the Malpighian bodies are radicles of the portal vein, and, through the portal vein, empty themselves, as in the higher tribes, into the plexus surrounding the uriniferous tubes. The only real difference between this form of kidney and that of Mammalia is that there is here a vessel bringing blood that has already passed through the capillaries of distant parts, to be added to that coming from the Malpighian bodies, and to circulate with it through the plexus surrounding the tubes. The efferent vessels of the Malpighian bodies run up to the surface, in order to throw their blood through the whole extent of the capillary

* *Vide antè*, p. 232-3.

plexus; which they would fail to do if they entered it in any other part."

"I have described the renal artery as being spent upon the Malpighian bodies; but in the hilum of the lobe it gives off, as in the higher animals, a few slender twigs to the coats of the excretory ducts, and of the larger vessels. The capillaries of these twigs are easily seen, and, in all probability, discharge themselves into the branches of the portal vein."

It will appear on referring to the plan (*fig.* 161.), that there is a direct relation between the size of the Malpighian bodies and the width of the lobe. At the apex of the lobe, where the uriniferous tubes are comparatively short, the Malpighian bodies are of small size, while at the base of the lobe, where the tubes are longer, the Malpighian bodies present a corresponding increase of size. It will presently be seen that this and other facts in the anatomy of this form of kidney, afford very important evidence as to the nature and office of the Malpighian bodies.

Mr. Bowman thus draws a comparison between the circulation through the kidney of the Boa and that through the liver: — "The circulation through this form of kidney may be aptly compared with that through the liver, as described by Mr. Kiernan in his invaluable paper on that gland. The plexus surrounding the tubes corresponds with the portal-hepatic plexus, which, in the lobules of the liver, invests the terminal portions of the bile-ducts. Both these plexuses are supplied with blood by a portal vein, derived chiefly from the capillaries of distant organs, but in part from those of the artery of the respective organs themselves. The only difference seems to be, that, while in the liver the branches of the artery are entirely given to the larger blood-vessels, ducts, &c., in the kidney a few only are so distributed, the greater number going through the Malpighian bodies, to perform an important and peculiar function. In both glands, however, all the blood of the artery eventually joins that of the portal vein. The emulgent vein of the kidney answers to the hepatic vein of the liver."

"*The comparison between the hepatic and the renal portal circulation* may be thus drawn in more general terms. The portal system of the liver has a double source, one extraneous, the other in the organ itself; so the portal system of the kidney, in the lower tribes, has a two-fold origin, one extraneous, the other in the organ itself. In both cases the extraneous source is the principal one, and the artery furnishing the internal source is very small. But in the kidney of the higher tribes the portal system has only one internal source, and the artery supplying it is proportionably large."

Mr. Bowman has ascertained that in all the vertebrate classes the Malpighian bodies have essentially the same structure; the capsule being formed by the dilated extremity of a uriniferous tube, into which a single mass of blood-vessels is inserted. But in some orders of animals there are modifications which merit notice. The most considerable of these regard the size of the Malpighian bodies. The following table from Mr. Bowman's paper exhibits their size in a few species, and subjoined to each measurement is that of the tube soon after its emergence. It will be seen that the diameter of the tubes varies far less than that of the Malpighian bodies.

Table of the Diameter of Malpighian Bodies, and of the Tubes emerging from them, in fractions of an English inch.

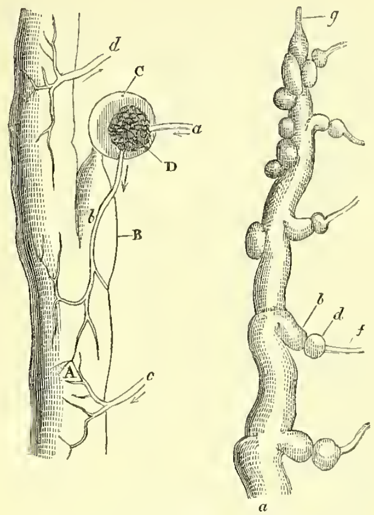
	Diameter of Malpighian Bodies.			Diameter of Tubes.
	Max.	Mean.	Min.	
Man	$\frac{1}{80}$	$\frac{1}{104}$	$\frac{1}{144}$	$\frac{1}{480}$
Badger	$\frac{1}{104}$	$\frac{1}{124}$	$\frac{1}{150}$	$\frac{1}{416}$
Dog	$\frac{1}{120}$	$\frac{1}{135}$	$\frac{1}{156}$	$\frac{1}{600}$
Lion	$\frac{1}{70}$	$\frac{1}{80}$	$\frac{1}{90}$	$\frac{1}{312}$
Cat	$\frac{1}{156}$	$\frac{1}{200}$	$\frac{1}{250}$	$\frac{1}{680}$
Kitten	$\frac{1}{208}$	$\frac{1}{260}$	$\frac{1}{312}$	$\frac{1}{1000}$
Rat	$\frac{1}{150}$	$\frac{1}{180}$	$\frac{1}{208}$	$\frac{1}{416}$
Mouse	$\frac{1}{220}$	$\frac{1}{255}$	$\frac{1}{312}$	$\frac{1}{770}$
Squirrel	...	$\frac{1}{207}$	...	$\frac{1}{770}$
Rabbit	...	$\frac{1}{156}$	...	$\frac{1}{625}$
Guinea Pig	...	$\frac{1}{208}$	...	$\frac{1}{600}$
Horse	$\frac{1}{55}$	$\frac{1}{70}$	$\frac{1}{90}$	$\frac{1}{416}$
Parrot	...	$\frac{1}{430}$	...	$\frac{1}{600}$ to $\frac{1}{700}$
Tortoise	...	$\frac{1}{240}$	...	$\frac{1}{480}$
Boa	$\frac{1}{230}$	$\frac{1}{400}$	$\frac{1}{540}$	$\frac{1}{540}$
Frog	...	$\frac{1}{250}$	...	...
Eel	...	$\frac{1}{207}$	...	...

According to Professor Müller* the kidney of the myxinoid fishes has a very simple structure. Before the publication of Mr. Bowman's paper Müller described the kidney of these fishes, as consisting of a long ureter extending on each side of the intestine, and sending off at intervals a small sac which terminates in a second closed sac, the junction of the two sacs being marked by a constriction. In the cavity of the closed sac there is a globular tuft of vessels, which is free on all sides except at one point, where the vessels pierce the investing capsule (*fig.* 162.). Prof. Müller, from a comparison of his own observations with those of Mr. Bowman, infers that the short tubes proceeding from the ureter in these fishes are analogous to the uriniferous tubes in the more highly organised kidneys, while the closed sac at the extremity of the tube is analogous to the Malpighian capsule; so that each *reneulus* in the myxinoid fish consists of an exceedingly short uriniferous tube terminating in a capsule, in which is suspended a globular tuft of vessels. The arterial branches which come directly from the aorta terminate, as in the higher animals, by piercing the capsule and forming a globular tuft within it. Müller had not an opportunity of tracing the exact distribution of the

* Untersuchungen uber die Eingeweide der Fische. Berlin, 1845.

blood after leaving the capsule, but he thinks it probable that the veins form a plexus on the outer surface of the tubes. It is to be regretted that Müller has not given some account of the microscopic appearances presented by the inner surface of these tubes, since without some observations on this point, and particularly with reference to the character of the epithelium, it is not possible to form a definite notion as to the exact nature of the parts in question.

Fig. 162.



1. The anterior extremity of the kidney of the *Bdellostoma Forsteri*, of the natural size.

a, the ureter; *b*, a short uriniferous tube proceeding from it; *d*, the capsule at the extremity of the tube; *f*, the arterial branch entering the capsule; *g*, the anterior blind extremity of the ureter.

2. Distribution of the blood-vessels in the kidney of the *Bdellostoma Forsteri*.

A, the ureter; B, a uriniferous canal proceeding from it; C, section of the capsule covering the blood-vessels; D, the vascular mass injected; *a*, the afferent vessel of the same; *b*, the efferent vessel; *c*, an artery unconnected with the vascular mass distributed to the ureter; *d*, a branch of the renal vein. This figure is slightly magnified. (*After Müller.*)

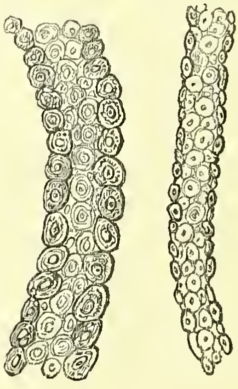
Epithelium. — In examining the epithelium of the kidney, it will be convenient to commence with that of the Malpighian bodies, and thence to trace this structure through the tubes into the pelvis and ureter. It is scarcely possible to overestimate the importance of a careful study of the epithelial cells in different parts of the kidney, since accurate observations upon this point must form the basis of an exact knowledge of the physiology of the gland, and of the pathological changes to which it is liable.

Epithelium of the Malpighian bodies. — With reference to the epithelium of the Malpighian bodies, it will suffice to recapitulate here what has already been fully detailed in speaking of the structure of these bodies. The epithelium of the Malpighian bodies consists of two distinct portions: first, that which covers the vessels; and, secondly, that which lines the capsule. The vessels of the Malpighian tuft appear to have in many instances a more or less complete investment of small, delicate, and transparent nucleated cells. (*Fig.* 160.) These cells differ entirely from those on the inner surface of the capsule, as well as from those which line the urinary tubes. The epithelium covering that part of the capsule which is contiguous to the orifice of the tube is very transparent, and clothed with vibratile cilia. This ciliated epithelium covers about one-third of the inner surface of the capsule; beyond this point the cilia cease, and the epithelium is of excessive delicacy and translucence (*figs.* 158. and 159.), while in many instances it is impossible to detect the slightest appearance of epithelium beyond the line where the cilia cease. The cilia in this situation have been observed only in reptiles and fishes, but they probably exist in all classes of Vertebrata.

Epithelium of the uriniferous tubes. — The epithelium of the uriniferous tubes presents itself in two distinct forms, the one kind existing in the convoluted tubes of the cortex, and the other in the straight tubes of the medullary cones. The epithelium in that part of the uriniferous tubes immediately continuous with the Malpighian capsule, presents the same characters as that which covers the contiguous portion of the capsule, consisting of delicate transparent particles, which in fishes and reptiles are furnished with vibratile cilia.

In the remaining portions of the tubes which intervene between the neck of the Malpighian capsules and the bases of the medullary cones, the epithelium presents itself under the form to which the term *spheroidal* or *glandular* is commonly applied.* The particles are of a more or less rounded form, and are thus distinguished from the flattened cells of the lamelliform or scaly variety of epithelium. (*Fig.* 163.) They usually form a single layer

Fig. 163.



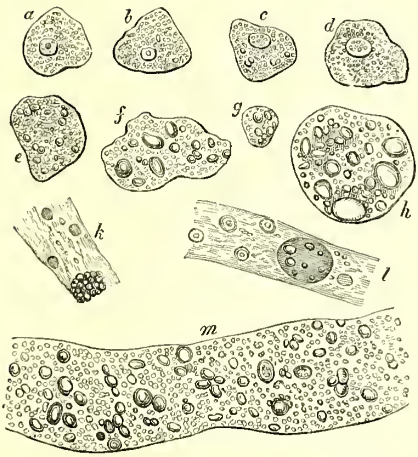
a, portion of a convoluted tube from the cortex of the kidney, showing the appearance of its epithelium.

b, portion of a straight tube with its epithelial lining from a medullary cone. Magnified 200 diameters.

* *Vide* article Mucous Membrane.

covering the surface of the basement membrane. They are granular and opaque, and appear to contain a considerable quantity of solid matter. The cell wall is very delicate, and when water is added to the specimen, the cells frequently fall in pieces very rapidly. In this respect the cells of the kidney differ remarkably from the hepatic cells, the latter having a much thicker and firmer wall, which offers a greater resistance to the action of water. The cells have a distinct nucleus, and in the centre of this in many instances a nucleolus is clearly visible. (*Fig.* 164.)

Fig. 164.



a, b, c, d, epithelial cells from a healthy kidney. *a* contains no oil; *b, c, d,* contain a few small oil globules in their interior. *e, f, g, h,* epithelial cells from a kidney affected with fatty degeneration; the oil globules are much larger and more numerous than in the cells from the healthy kidney. *m,* portion of a urinary tube from a kidney affected with fatty degeneration. *k, l,* fibrinous moulds of the urinary tubes from the urine of a patient with fatty degeneration of the kidney, each cylindrical mould entangles blood corpuscles, and a cell having a considerable number of oil globules in the interior. *Medic. Chir. Trans.* vol. xxix. Magnified 400 diameters.

Another interesting feature in the renal secreting cells consists in their containing in some cases minute particles of oil. In a perfectly healthy kidney, the quantity of oil contained in the epithelium is very small; sometimes, indeed, it is difficult to find any cells which contain even the most minute particles of oil, while in other instances, where there is every reason to consider the organ quite healthy, the quantity of oil is much more considerable. When this material accumulates beyond a certain extent which it is difficult to define, it must be considered as morbid, and a great excess of oil in the secreting cells constitutes a main feature of one of the most serious and intractable diseases to which the kidney is liable.

The epithelium lining the straight tubes of the pyramids differs essentially from that of the convoluted tubes; the latter, as before stated, is the true spheroidal or glandular variety of epithelium; while the former approaches more nearly to the lamelliform or scaly variety. Its particles are smaller and more flattened, so that the epithelium in the medullary cones constitutes a much smaller proportion of the thickness of the tubes than does that in the convoluted tubes of the cortex. (*Fig.* 163. *b.*) The canal of the tubes in the medullary cones is also greater in proportion to the thickness of the wall than in the convoluted tubes. The cells in this portion of the tubes have uniform, smooth, and transparent walls, and their interior is less opaque and granular than is the case with the glandular cells before described. Another distinctive character consists in the fact of these cells seldom, if ever, containing oil.

Ciliary motion in the tubes. — The preceding description of the epithelial lining of the uriniferous tubes corresponds in most particulars with the usually received account of these structures. There now remain to be stated certain facts which probably are not generally known even to those who are accustomed to make microscopical examinations of the kidney. In 1845, A. Kölliker published a short paper *, in which he mentions the interesting fact, that in the kidney of the embryo lizard the uriniferous tubes are lined by an epithelium remarkable for distinctly developed ciliary processes, which may be seen in vigorous action for some time after the death of the animal. The ciliated epithelium, according to Kölliker's observation, exists throughout the whole length of the tubes, except at the extremities next the common excretory duct. He also observed the cilia at the entrance of the Malpighian capsule. In a note appended to the same paper, the editor (J. Müller) states that he has observed the same phenomenon in the uriniferous tubes of a fish (Raia clavata). The cilia are very large and long; they are directed along the axis of the tube, and have a wavy motion like that of a whip-lash.

In the spring of the present year, before I was aware of the observations just now referred to, while examining the kidney of the newt (Triton and Lissotriton), I was surprised to find vibratile cilia in active motion, not only within the Malpighian capsule as described by Mr. Bowman in the frog, but apparently extending throughout the whole length of the uriniferous tubes. I have since looked for this wonderful phenomenon in many of the animals just now mentioned, and have never failed to detect it in any one of the kidneys examined. The part of the kidney most favourable for the examination of this ciliary motion is the anterior extremity, where it is very thin and transparent, so that after being cut away with sharp scissors it requires no further preparation for micro-

* Ueber Flimmerbewegungen in den Primordial-Nieren. Müller's Archiv. 1845, and Edinburgh Med. and Surg. Journal, vol. lxviii.

scopical examination. In a part thus prepared, I have sometimes seen the cilia in rapid action throughout the whole length of every tube in the field of the microscope, and a more wonderful or beautiful sight can scarcely be imagined. The motion commences within the Malpighian capsule; the little particles floating in the liquid of the capsule are darted into the orifice of the tube with marvellous precision, and thence they are directed onwards through the windings of the tube in a current of liquid, which is propelled with great regularity and speed. Much violence in tearing up the specimen for examination appears to arrest the motion; and when water is added to the preparation, the epithelial particles swell and fill up the cavity of the tube, and so the motion is retarded. When the cilia are in slow motion, their form and the direction of their movement may easily be seen; but when the motion has entirely ceased, I have never been able to see them distinctly, even with the best object glasses. The motionless cilia appear to collapse and fall upon the surface of the epithelium, and so become invisible. Since my attention was first directed to the phenomenon in question, I have had but little time to search for it in other animals; but there appears reason to believe that it exists in most of the higher animals, and probably even in man. The result of my own observations may be thus briefly stated: — In the newt I have searched for ciliary motion in the tubes many times, and have never failed to find it in any kidney which I have examined. I have searched for it in the frog twice (*i. e.* in two individuals), and found the ciliary motion very distinct in a considerable portion of one tube. I have examined one snake, and observed the motion very distinctly throughout a large extent of several of the tubes, as well as in the Malpighian capsules. I have searched for the phenomenon in the kidneys of some of the smaller Mammalia, as, for instance, in the mouse and the rabbit, but hitherto without success. I am not aware that any other observations with reference to this subject have been published, but possibly there may be some with which I am not acquainted.

Epithelium of the pelvis and ureter. — The epithelium of the pelvis and ureter requires only a brief mention; it belongs to the lamelliform or scaly variety, and consists of flattened, delicate, transparent scales, having an angular outline caused by their lateral apposition, and a nucleus which is generally eccentric.

Function of the Malpighian bodies and uriniferous tubes. — Before concluding this part of our subject, it appears desirable to make some allusion to the probable office of the several parts of the kidney, whose structure has passed under review. Mr. Bowman, in the paper to which reference has so often been made, has propounded a theory as to the office of the Malpighian bodies which I believe will soon be admitted as a true and well-established doctrine, based as it is upon accurate observation, and confirmed by sound reasoning and analogy. The theory in question, and the facts and arguments in support of it, are thus clearly stated by Mr. Bowman: —

"Reflecting on this remarkable structure of the Malpighian bodies, and on their singular connection with the tubes, I was led to speculate on their use. It occurred to me that, as the tubes and their plexus of capillaries were probably, for reasons presently to be stated, the parts concerned in the secretion of that portion of the urine to which its characteristic properties are due (the urea, lithic acid, &c.), the Malpighian bodies might be an apparatus destined to separate from the blood the watery portion. This view, on further consideration, appears so consonant with facts, and with analogy, that I shall in a few words state the reasons that have induced me to adopt it. I am not unaware how obscure are the regions of hypothesis in physiology, and shall be most ready to renounce my opinion, if it be shown to be inconsistent with truth.

"In extent of surface, internal structure, and the nature of its vascular network, the membrane of the uriniferous tubes corresponds with that forming the secreting surface of other glands. Hence it seems certain that this membrane is the part specially concerned in eliminating from the blood the peculiar principles found in the urine. To establish this analogy, and the conclusion deduced from it, a few words will suffice. 1. The extent of surface obtained by the involutions of this membrane will by most be regarded as itself sufficient proof. But, 2. Its internal surface is conclusive. Since epithelium has been found by Purkinje and Henle in such enormous quantities on the secreting surface of all true glands, its use cannot be considered doubtful. It never forms less than $\frac{19}{20}$ths of the thickness of the secreting membrane, and in the liver it even seems to compose it entirely, for there I have searched in vain for a basement tissue, like that which supports the epithelium in other glands. The epithelium, thus chiefly forming the substance of secreting membrane, differs in its general characters from other forms of this structure. Its nucleated particles are more bulky, and appear from their refractive properties to contain more substance, their internal tissue being very finely mottled, when seen by transmitted light. In these particulars the epithelium of the kidney-tubes is eminently allied to the best-marked examples of glandular epithelium. 3. The capillary network surrounding the uriniferous tubes is the counterpart of that investing the tubes of the testis, allowance being made for the difference in the capacity of these canals in the two glands. It corresponds with that of all true glands in lying on the deep surface of the secreting membrane, and in its numerous vessels everywhere anastomosing freely with one another.

"These several points of identity may seem too obvious to be dwelt upon, but I have detailed them in order to show that in all

these respects the Malpighian bodies differ from the secreting parts of true glands. 1. The Malpighian bodies comprise but a small part of the inner surface of the kidney, there being but one to each tortuous tube. 2. The epithelium immediately changes its characters, as the tube expands to embrace the tuft of vessels. From being opaque and minutely mottled, it becomes transparent, and assumes a definite outline; from being bald, it becomes covered with cilia (at least in reptiles, and probably in all classes); and in many cases it appears to cease entirely a short way within the neck of the Malpighian capsule. 3. The blood-vessels, instead of being on the deep surface of the membrane, pass through it and form a tuft on its free surface. Instead of the free anastomoses elsewhere observed, neighbouring tufts never communicate, and even the branchlets of the same tuft remain quite isolated from one another.

"Thus the Malpighian bodies are as unlike, as the tubes passing from them are like, the membrane which, in other glands, secerns its several characteristic products from the blood. To these bodies, therefore, some other and distinct function is with the highest probability to be attributed.

"When the Malpighian bodies were considered merely as convoluted vessels, without any connection with the uriniferous tubes, no other office could be assigned them than that of delaying the blood in its course to the capillaries of the tubes, and the object of this it was impossible to ascertain. Now, however, that it is proved that each one is situated at the remotest extremity of a tube, that the tufts of vessels are a distinct system of capillaries inserted into the interior of the tube, surrounded by a capsule formed by its membrane, and closed everywhere except at the orifice of the tube, it is evident that conjectures on their use may be framed with greater plausibility.

"The peculiar arrangement of the vessels in the Malpighian tufts is clearly designed to produce a retardation in the flow of the blood through them; and the insertion of the tuft into the extremity of the tube, is a plain indication that this delay is subservient in a direct manner to some part of the secretive process.

"It now becomes interesting to inquire, in what respect the secretion of the kidney differs from that of all other glands, that so anomalous an apparatus should be appended to its secerning tubes. The difference seems obviously to lie in the quantity of aqueous particles contained in it; for how peculiar soever to the kidney the proximate principles of the urine may be, they are not more so than those of other glands to the organs which furnish them.

"This abundance of water is apparently intended to serve chiefly as a menstruum for the proximate principles and salts which this secretion contains, and which, speaking generally, are far less soluble than those of any other animal product. This is so true, that it is common for healthy urine to deposit some part of its dissolved contents on cooling.

"If this view of the share taken by the water be correct, we must suppose that fluid to be separated either at any point of the secreting surface along with the proximate principles, as has hitherto been imagined, or else in such a situation that it may at once freely irrigate the whole extent of the secerning membrane. Analogy lends no countenance to the former supposition; while to the latter, the singular position and all the details of the structure of the Malpighian bodies, give strong credibility.

"It would indeed be difficult to conceive a disposition of parts more calculated to favour the escape of water from the blood than that of the Malpighian body. A large artery breaks up in a very direct manner into a number of minute branches, each of which suddenly opens into an assemblage of vessels of far greater aggregate capacity than itself, and from which there is but one narrow exit. Hence must arise a very abrupt retardation in the velocity of the current of blood. The vessels in which this delay occurs are uncovered by any structure.* They lie bare in a cell from which there is but one outlet, the orifice of the tube. This orifice is encircled by cilia in active motion, directing a current towards the tube. These exquisite organs must not only serve to carry forward the fluid already in the cell, and in which the vascular tuft is bathed, but must tend to remove pressure from the free surface of the vessels, and so to encourage the escape of their more fluid contents. Why is so wonderful an apparatus placed at the extremity of each uriniferous tube, if not to furnish water to aid in the separation and solution of the urinous products from the epithelium of the tube?"

There is nothing which appears to afford greater support to Mr. Bowman's theory than the structure of the kidney of the boa, when considered in connexion with the fact that the urine in this animal is excreted in an almost solid form. It will be remembered† that the greater part of the blood supplied to the kidney of the boa is derived from a vein which comes from the posterior part of the body; this vein forms the plexus which surrounds the uriniferous tubes, and from which, according to Mr. Bowman, the solids of the urine are excreted. The renal artery, which is comparatively of small size, is distributed to the Malpighian bodies, as in the higher animals, and the efferent vessel joins the portal vein. The solid urine of the serpent seems a necessary consequence of the peculiar distribution of the blood-vessels; the small Malpighian bodies pour out a scanty stream of water sufficient only to carry through the tubes the large quantities of solid matter which the more numerous and larger vessels distributed on the outer surface of the tubes are continually supplying.

* With reference to this point, *vide antè*, p. 248-9.

† *Vide antè*, p. 250.

Another fact confirmatory of Mr. Bowman's theory has been observed by myself.* In examining the kidneys of persons who had died jaundiced, and in whose urine there had been a large quantity of bile, I observed that the tubes were stained of a deep yellow colour by the bile in their epithelical cells, and that this yellow colour ceased abruptly at the neck of the Malpighian capsule, and in no instance did it affect any part of the tissue of the Malpighian bodies. There are certain other pathological phenomena, which Mr. Bowman's theory very much assists to explain, and which in their turn afford important evidence in support of the doctrine in question.

The office of secreting the solids of the urine is limited to the convoluted portions of the tubes. The straight tubes of the pyramids probably have no secreting power, but act merely as excretory ducts to convey the secreted products from the cortical portion of the gland. The different function of these two portions of the tubes is sufficiently manifested by two facts: — 1st. By the difference in the character of their epithelial lining; 2dly. By the fact, that when the cortical portion of the kidney is the seat of a morbid deposit in consequence of the attempted excretion of abnormal products by the epithelial cells in the convoluted tubes, the medullary portion of the gland is very commonly free from all trace of the same morbid deposit. This is very frequently observed in instances of fatty degeneration, as well as in the earlier stages of the inflammatory diseases of the kidney.

PART III.— PATHOLOGY OF THE KIDNEY.

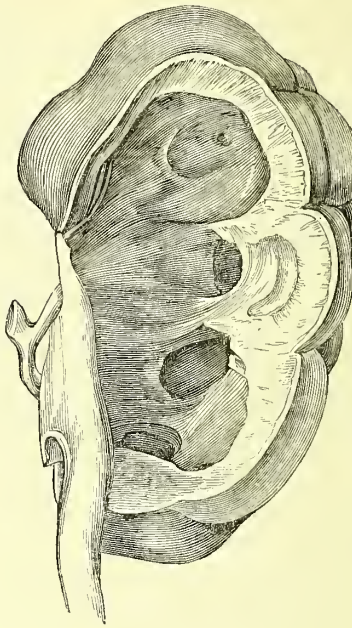
It will not be possible within the limits of this article to give more than an outline of the pathology of the kidney. The subject is one of such great interest and importance that it requires a much more extended consideration than can here be assigned to it.

The diseases of the kidney may be arranged in two distinct classes: the first class including those which are the result of some cause acting locally, such as retention of the urine in consequence of stricture, the mechanical irritation of a stone impacted in the kidney, or a blow on the loins; while in the second class are included those diseases which are the result of a constitutional cause which acts upon the kidney by inducing an abnormal condition of the blood.

We shall allude very briefly to the first class of diseases, and then proceed to the consideration of those diseases to which the kidney is liable in consequence of a deteriorated condition of the blood.

Disease of the kidney from retention of urine. —*Fig.* 165. represents a condition of the kidney which commonly results from an impeded escape of the urine. The ureter pelvis and infundibula become much dilated, and the cortical substance expanded and lobular on the surface, the depressions between the lobules resulting from the binding down of the tissue by the interlobular septa, in the

Fig. 165.



Section of the kidney from a patient who had stricture. The pelvis and infundibula are much dilated, the cortical portion is expanded, and its surface lobular. The parts are reduced about one third in the drawing.

intervals of which the glandular structure is protruded by the distending force from within. The mucous membrane frequently becomes ulcerated, inflammatory deposits occur in the substance of the kidney, and so the gland is destroyed by a slow atrophy, or more rapidly by suppurative inflammation. Both kidneys are usually affected, but in different degrees. On a microscopical examination of the kidney thus diseased, pus and other inflammatory deposits are found. The deposits are not confined to the tubes, but they occur irregularly throughout the gland, so as in many instances to obliterate all appearance of tubular structure.

Disease of the kidney from renal calculi. — When a calculus forms in the kidney, it may lead to very different results according to its size and position. If of small size, it may pass down the ureter and so get into the bladder; or if it be too large to pass through the ureter, it may, by becoming impacted in the canal, and so obstructing the flow of urine, give rise to a rapidly destructive suppurative inflammation, or it may lead to complete atrophy of the gland. It sometimes happens that several calculi become impacted in the pelvis of one or both kidneys, causing ulceration of the surrounding tissue, and leading in some instances to a complete disorganisation of the gland.

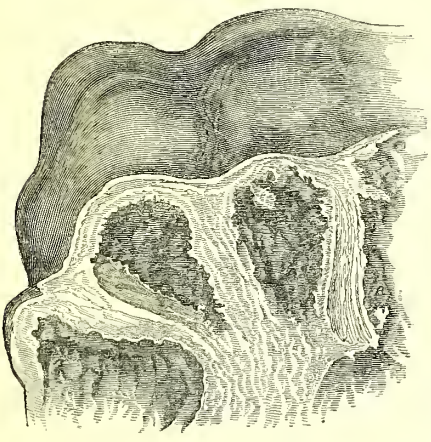
* Med. Chir. Trans. vol. xxx.

Disease of the kidney from external violence— is not of common occurrence. One case of the kind has occurred to myself. A strong man in robust health received a violent blow on the loins from a bludgeon; he suffered much pain, and within a short time after the receipt of the injury he had hæmaturia. The bleeding recurred at intervals during several months, and was succeeded by a discharge of purulent matter with the urine. The purulent discharge continued for a period of more than a year, when the poor man died much emaciated. On a post mortem examination, the right kidney was found completely destroyed by suppurative inflammation; there was no strumous deposit in the kidney or in any other organ. There was no calculus. The left kidney was quite sound.

Extension of disease from other organs to the kidney.—The kidney sometimes becomes involved in malignant or other disease affecting the intestines and other adjacent viscera. Allusion has already been made to a preparation in the Museum of King's College, in which there is a communication between an abscess in the psoas muscle and the canal of the ureter.

Diseases resulting from a constitutional cause.—Scrofulous disease of the kidney occurs in the form of small scattered deposits of tubercular matter, or it presents itself in the form of a thick curdy deposit which leads to the formation of a large scrofulous abscess, the cavity of which is subdivided by septa formed by the thickened interlobular cellular tissue. (*fig.* 166.) The scrofulous deposit commonly

Fig. 166.

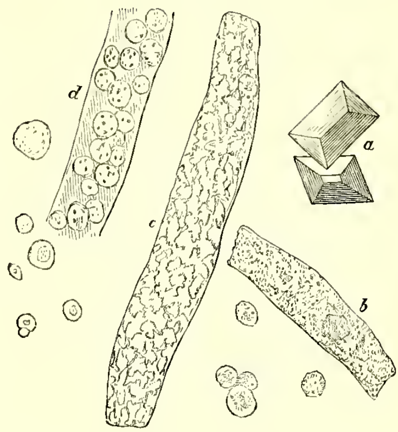


Scrofulous abscess in the kidney. The cavity of the abscess is divided by septa, which are formed by the interlobular cellular tissue, thickened by an interstitial deposit of strumous matter. The glandular structure has been destroyed by suppurative inflammation.

extends over the mucous membrane of the ureter, which becomes much thickened.

Acute suppurative nephritis is not a common disease, but it is a very serious and a very fatal one. In one case it supervened upon chronic disease of the kidney, in consequence of the intemperate use of fermented liquors by a man whose general health was much disordered, and who had been subject for several months to successive crops of boils and carbuncles about the neck and shoulders. He died in about a week after symptoms of suppurative nephritis had manifested themselves. The nature of the disease was detected at the very commencement by a microscopical examination of the urine (*fig.*167). Both kidneys

Fig. 167.



Deposit in the urine of a patient labouring under acute suppurative nephritis. *a*, crystals of triple phosphate; *b*, *c*, *d*, moulds from the tubes of the kidney, the last entangling pus corpuscles. Some free pus corpuscles are scattered about the field. Magnified 200 diameters.

were much enlarged, evidently from a recent attack of acute inflammation, numerous small points of suppuration were scattered through them, and the left contained two large recent abscesses. This case occurred in King's College Hospital, under the care of Dr. Todd.

Acute desquamative nephritis.—This form of disease occurs very frequently as a consequence of scarlatina, and is occasionally produced by other animal poisons, as for instance that of typhus fever, small-pox, or measles. The same condition of kidney very commonly occurs amongst the poor in large towns and elsewhere, as a consequence of that deteriorated condition of the blood, which results from an insufficient supply of animal food; and it sometimes occurs as a consequence probably of a similarly deteriorated condition of the blood in persons who are much reduced by long-continued disease, as for instance secondary syphilis or chronic abscess.

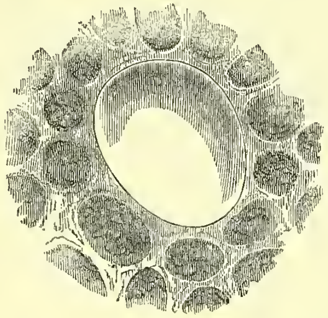
The kidney in these cases is enlarged, apparently by the deposit of a white material in the cortical substance; the vessels in the cortical portion where they are not compressed by this new material, are injected, and of a bright red hue; the medullary cones are of a dark red colour, in consequence of the large veins which occupy these portions of the gland being distended with blood. The ap-

pearance of the entire organ is quite that of a part in a state of acute inflammation.

When the kidney has been in a softened condition before the occurrence of the inflammatory disease, as often happens in elderly persons, the lobules on the surface appear larger and coarser than natural; the veins being less compressed than when the natural texture of the kidney is firmer and more unyielding, are much distended with blood, so that the entire organ is of a dark slate colour.

On a microscopical examination the convoluted tubes are seen filled, in different degrees, with nucleated cells, differing in no essential character from those which line the tubes of the healthy gland (*fig.* 168). The

Fig. 168.



Section of a portion of inflamed kidney. The tubes appear as if divided into distinct globular and oval portions; this appearance results from the manner in which the tubes are packed in the meshes of the fibrous matrix, so as to be concealed where they are crossed by the fibrous tissue, and visible in the intervals. The tubes are rendered opaque by an accumulation of epithelium, the outline of the cells being invisible on account of their being closely packed. A Malpighian body in the centre of the mass appears transparent and healthy. Magnified 200 diameters. *Med. Chir. Trans.* vol. xxx.

Malpighian bodies are for the most part transparent and healthy, but the vessels of the tuft are sometimes rendered opaque by an accumulation of small cells on their surface. Some of the tubes contain blood, which has doubtless escaped from the gorged Malpighian vessels. There is no deposit exterior to the tubes.

The condition of the urine in these cases is clearly indicative of the process going on in the kidney. After it has been allowed to stand for a short time, a sediment forms; and on placing a portion of this under the microscope, there may be seen blood-corpuscles, with epithelial cells in great numbers, partly free and partly entangled in cylindrical fibrinous casts of the urinary tubes*, and very commonly numerous crystals of lithic acid are present (*fig.* 169).

As the disease subsides, which under proper treatment it usually does in a few days, the blood, fibrinous casts, and epithelial cells diminish in quantity, and finally disappear; but traces of the casts may be seen some days after the urine has ceased to coagulate, on the application of heat or nitric acid.

Fig. 169.

Portion of a tube much dilated and divided by septa which correspond with the rings of fibrous tissue in the microscopic specimen. See *fig.* 149, *b*. The cluster about *b* includes two fibrinous moulds of the urinary tubes, entangling epithelial cells and blood corpuscles, two free epithelial cells, and three crystals of lithic acid from the urine in a case of "acute desquamative nephritis."

c, A mass of oily matter from the urine.

d, A cluster of octohedral crystals of oxalate of lime.

Magnified 200 diameters. *Med. Chir. Trans.* vol. xxx.

The changes above described as occurring in the kidney are the result of a modification of the natural process of secretion produced by the presence of abnormal products in the blood. These products are eliminated by an excessive development of epithelial cells which are thrown into the tubes and washed out with the urine. The desquamation from the inner surface of the tubes is analogous to that which occurs on the skin subsequent to the eruption of scarlatina. I have, therefore, proposed to apply the term "acute desquamative nephritis" to this form of disease.*

Chronic desquamative nephritis is essentially of the same nature as the acute form of the disease. Its most frequent cause is the gouty diathesis, and it very rarely occurs except in those who are addicted to the use of alcoholic drinks.† In the earlier stage of the disease the kidney is of the natural size, or very slightly enlarged, and the structure of the organ appears confused, as if from the admixture of some abnormal product; there is

* The fibrinous moulds of the kidney tubes, as seen in albuminous urine, were first observed by the late Dr. F. Simon of Berlin.

* See the author's paper on this subject in the Med. Chir. Trans. vol. xxx.

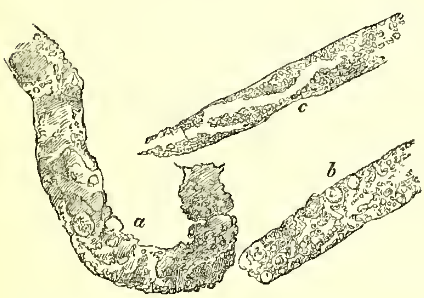
† This form of diseased kidney was first described by Dr. Todd, under the name of gouty kidney, in a clinical lecture which was delivered in June 1846, and published in the Medical Gazette for June 1847. In this lecture Dr. Todd alludes particularly to the destruction of the secreting cells, and the consequent deficient excretion of the solid constituents of the urine.

also some increase of vascularity. As the disease advances, the cortical portion gradually wastes, and the entire organ becomes contracted, firm, and granular, the medullary cones remaining comparatively unaffected even in the most advanced stages; simultaneously with the diminution in the size of the kidney there is a decrease of vascularity. These changes occur very gradually; the disease having a duration in most cases of many months, and in some even of several years.

On placing thin sections of the kidney under the microscope, some of the tubes are seen to be in precisely the same condition as in a case of acute desquamative nephritis: they are filled and rendered opaque by an accumulation within them of nucleated cells, differing in no essential respect from the normal epithelium of the kidney. This increase in the number, and this slight alteration in the character of the epithelial cells are the result of the elimination by the kidney of mal-assimilated products, which are being continually developed in gouty and intemperate subjects, and which are not normal constituents of the renal secretion.

There would evidently be a certain limit to the number of cells which can be formed in any one of the uriniferous tubes; for although some of the cells escape with the liquid part of the secretion, and so may be seen in the urine, as in a case of acute desquamative nephritis, yet in many of the tubes the cells become so closely packed that the further formation of cells becomes impossible, and the process of cell-formation, and consequently of secretion within these tubes, is arrested. The cells, thus formed and filling up the tube, gradually decay and becomes more or less disintegrated. While these changes are occurring in the tubes, the Malpighian bodies frequently continue quite healthy, their capsules for the most part transparent, and the vessels in their interior perfect. From these vessels water, with some albumen and coagulable matter, is continually being poured into the tubes; and, as a consequence of this, the disintegrated epithelial cells are washed out by the current of liquid flowing through the tubes, so that, on examining the sedimentary portion of the urine, we find in it cylindrical moulds of the urinary tubes, composed of epithelium in different degrees of disintegration, and rendered coherent by the fibrinous matter which coagulates amongst its particles. (*fig.* 170.)

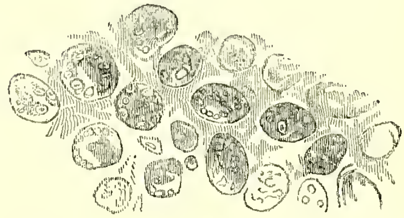
Fig. 170.



Casts of the urinary tubes, composed of fibrinous matter and disintegrated epithelium from the urine, in a case of chronic desquamative nephritis. Magnified 200 diameters. *Med. Chir. Trans.* vol. xxx.

There is reason to believe that when the process of cell-development and of secretion have once been arrested by a tube becoming filled with its accumulated contents, the tube never recovers its lining of normal epithelial cells; but when the disintegrated epithelium has been washed away from the interior of the tube, the basement membrane may be seen in some cases entirely denuded of epithelium; in other tubes a few granular particles of the old and decayed epithelium remain (*fig.* 171.);

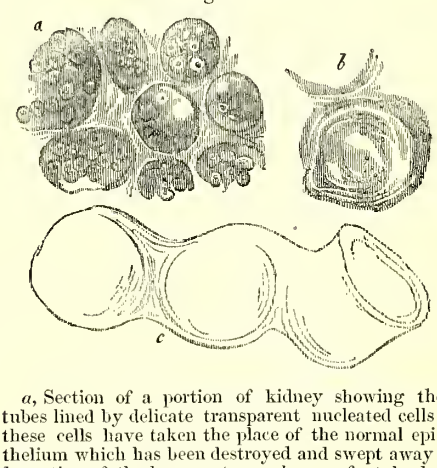
Fig. 171.



Section of a portion of kidney, showing the tubes deprived of their epithelium by "chronic desquamative nephritis." The tubes as they lie packed in the meshes of the fibrous matrix have an appearance somewhat like that of globular and oval transparent vesicles or cysts. See *figs.* 149 *c* and 150. Magnified 200 diameters. *Med. Chir. Trans.* vol. xxx.

and again, in other instances, the interior of a tube which has been deprived of its proper glandular epithelium is seen lined by small delicate transparent nucleated cells (*fig.* 172.),

Fig. 172.

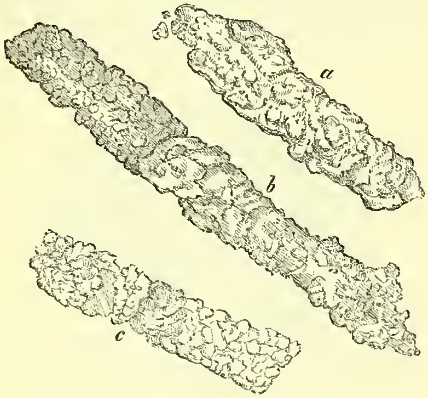


a, Section of a portion of kidney showing the tubes lined by delicate transparent nucleated cells; these cells have taken the place of the normal epithelium which has been destroyed and swept away; *b*, portion of the basement membrane of a tube deprived of its epithelium, and contracted by its elasticity into an irregular globular form after being detached from the surrounding tissues; *c*, portion of a tube much dilated, and bulging in the intervals of the matrix; the constricted portions correspond with the surrounding rings of fibrous tissue. Magnified 200 diameters. *Med. Chir. Trans.* vol. xxx.

very similar to those which may sometimes be seen covering the vessels of the Malpighian tuft. (*Vide antè, fig.* 160.)

After the tubes have lost their normal epithelial lining they may undergo one of the three following changes. 1. In some instances a peculiar whitish glistening material is thrown into the tubes, some of which escapes with the urine in the form of cylindrical moulds of the tubes, the appearance of which as seen in the urine is somewhat imperfectly represented in *fig.* 173. The effect

Fig. 173.



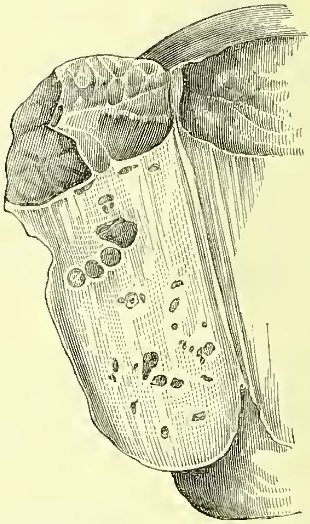
Cylindrical moulds of the urinary tubes composed of a peculiar whitish glistening material, which is sometimes effused into the tubes in the advanced stages of chronic nephritis. From the urine. Magnified 200 diameters.

of this material being effused into the tubes appears to be to obliterate them, and in some instances it apparently becomes organised into fibrous tissue.

2. Another change which the tubes undergo in consequence of losing their epithelial lining, is that of becoming atrophied. The power of separating the solid urinary constituents from the blood resides in the epithelial cells which line the convoluted tubes. After the destruction of the cells the secreting power is lost, and as the normal action of the cells is certainly one of the essential conditions for maintaining the continued flow of blood to the tubes, so the removal of the cells is very commonly followed by a diminished afflux of blood, and a consequent wasting of the tubes.

3. Another change consequent upon the destruction of the epithelial cells is, in a certain sense, the reverse of the preceding. The tubes appear to retain the power of secreting serum, which fills and dilates the tube in consequence of its escape being prevented by epithelial débris choking up the lower extremity of the tube. When once a tube is brought into this condition the process of dilatation may proceed to an almost unlimited extent. The tube bulges in the intervals of the fibrous matrix, and assumes the appearance represented in *fig.* 172 *c*. These dilated tubes form the serous cysts which are so commonly seen in the cortical portion of the kidney. And it is remarkable that the moniliform appearance of the dilated tubes, as seen in the microscopic specimens, is in many instances preserved even when the tube is so much dilated as to form cysts visible to the naked eye. (*Fig.* 174.)

Fig. 174.



Section of a portion of kidney in which serous cysts have been developed. At *a* there is a series of four cysts which are probably formed by the dilatation of a single tube. Compare this with *fig.* 172. From a specimen in the museum of King's College. Natural size.

Mr. Simon, in a paper on " Subacute Inflammation of the Kidney,"* has propounded the theory that these cysts are greatly dilated epithelial germs, which become thus monstrously developed in consequence of the destruction of the basement membrane of the tubes.

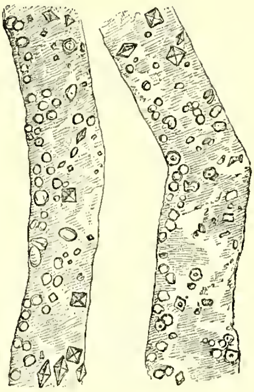
If Mr. Simon's account of these cysts were correct they would be in fact hydatid cysts. I am not prepared to deny that cysts are ever formed in the kidney by the development of isolated cells, as described by Mr. Simon; it is very possible that such an occurrence may be not unfrequent, although it has hitherto escaped my observation. But there can, I think, be no doubt in the mind of any one who will carefully examine the subject, that the appearances described and figured by Mr. Simon are produced simply by the packing of the tubes in the fibrous network which surrounds and partially conceals them. The best safeguard against a misinterpretation of appearances in diseased specimens is a careful study of the healthy tissues. The peculiar cyst-like appearance of the tubes in cases of chronic nephritis results from the transparency of the tubes when deprived of their epithelial lining. This delicate and

* Med. Chir. Trans. vol. xxx.

transparent appearance of the tubes, which in the human kidney is the result of disease, may constantly be seen in the kidneys of some of the smaller animals; as, for example, those of a mouse or a young rabbit. On examining thin sections of the kidneys of these animals it will be found that the delicate and semitransparent tubes, embedded in the surrounding fibrous network, constantly present more or less of the cyst-like appearance represented in *fig.* 171. It can scarcely be supposed that these appearances in the kidney of the mouse indicate the existence of isolated cells. In short, Mr. Simon's theory of renal cysts is so opposed to all analogy, and so entirely unsupported by facts, that it appears needless to occupy the time of our readers by a further detail of facts and arguments in opposition to it.

Renal Hæmorrhage. — Under this head I will allude in a few words to a condition of kidney which I have never had an opportunity of examining in the dead subject, but the nature of which is sufficiently manifested by the symptoms, and particularly by the condition of the urine, as ascertained by a microscopical examination during life. It is well known that great irritation of the urinary organs is a frequent consequence of the internal administration of oil of turpentine, or the application of cantharides to the cutaneous surface. The urine in these cases is generally bloody, and is passed very frequently and in small quantities; there is great pain and irritation about the kidneys and bladder; but there are no symptoms of suppression of urine, such as drowsiness and tendency to inflammation of internal organs, symptoms which are present, in a greater or less degree, in all cases of "desquamative nephritis." In the last-mentioned cases the epithelial lining of the urinary tubes is the seat of disease, and the imperfect elimination of the solid constituents of the urine is a necessary consequence of the pathological changes which the secreting epithelium undergoes. In the condition of kidney now under consideration the Malpighian capillaries appear to be the only parts of the organ primarily affected. The irritation produced by the turpentine or the cantharides leads to engorgement of the Malpighian tufts, which commonly ends in rupture of the vessels, hæmorrhage into the tubes, and so the admixture of blood with the urine. On a microscopical examination of the urine fibrinous moulds of the tubes may be seen in great numbers (*fig.* 175), blood corpuscles are entangled in the fibrine, but no epithelium is found combined with them. The inference is, that the epithelial lining of the urinary tubules is unaffected, and this conclusion is further supported by the fact already mentioned, viz., the absence of the usual symptoms resulting from a deficient excretion of urea and the other solid constituents of the urine. I have never seen a fatal case of strangury; but when hæmorrhage from the Malpighian capillaries has occurred in connection with other pathological conditions which have terminated fatally, hæmorrhagic spots are seen scattered over the surface and through the cortical substance of the kidney.

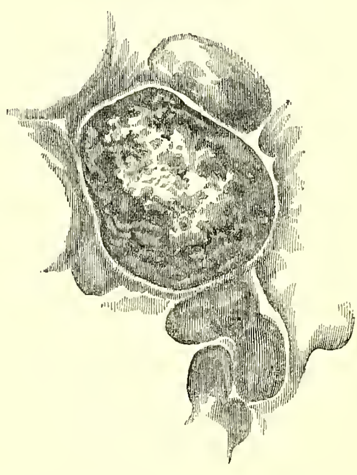
Fig. 175.



Fibrinous moulds of the urinary tubules from the urine of a patient who had strangury after taking oil of turpentine. Some blood corpuscles are entangled in the fibrine, as well as some octohedral crystals of oxalate of lime which the patient was excreting at the time the hæmorrhage occurred. It is important to observe that in this form of fibrinous mould there is no epithelium from the tubes. Magnified 200 diameters.

These spots, when submitted to a microscopical examination, are found to be composed of convoluted tubes filled with blood which has escaped from the Malpighian capillaries, and after filling the capsule has passed into the tube (*fig.* 176). This fact was first pointed out by Mr. Bowman.

Fig. 176.



Malpighian capsule and portions of the urinary tubes containing blood which has escaped from the Malpighian capillaries. Magnified 200 diameters. See also *fig.* 149 *d.*

The condition of kidney to which turpentine and cantharides give rise may result from

the irritation produced by certain products developed within the body. I have met with two well marked cases of this kind, in which the characters of the urine, as revealed by a microscopical examination, and the other attendant symptoms were the same. In both cases the symptoms were of short duration. When the blood in cases of hæmaturia is found to be moulded in the urinary tubes, there can of course be no doubt as to the hæmorrhage being renal. During the first few hours of an attack of hæmaturia it commonly happens that the blood escapes from the kidney before it has coagulated, and at this period of the attack a large quantity of the blood will be found not to have the form of cylindrical moulds when examined by the microscope, but even in this case a careful examination will always detect some moulds, and that will suffice for the diagnosis; and at a later period of the attack, when the hæmorrhage occurs more slowly it will be found that nearly all the blood has been moulded into the urinary tubes before it has escaped from the kidney. When renal hæmorrhage is produced by the irritation of a calculus impacted in the pelvis or the ureter, the blood does not present the fibrinous moulds in question.

Fatty degeneration of the kidney occurs under two distinct forms. In the first form of the disease in question, the kidneys are usually large, smooth, soft, pale, and mottled, and frequently they are scattered over with hæmorrhagic spots. On a microscopical examination, there is found to be a great increase in the size and number of the oil globules which exist in small quantities in the epithelial cells of the healthy gland. (*See fig.* 164.) The urinary tubes are filled and distended by the gorged epithelial cells, the dilated tubes compress the capillary plexus on their exterior, and hence, in consequence of passive congestion of the Malpighian vessels, the serum of the blood gets mixed with the urine, which thus becomes albuminous; and when the obstruction of the circulation is still greater the colouring matter of the blood escapes from the delicate Malpighian vessels and fills the tubes, giving rise to the hæmorrhagic spots before mentioned.

It is only that form of epithelium whose office it is to excrete the solid portion of the urine which becomes gorged with oil; the delicate epithelium covering the Malpighian vessels, as well as that which lines the straight tubes of the medullary cones, retains its normal condition: the reason of these parts remaining healthy while the epithelium of the convoluted tubes becomes greatly changed, as well in cases of fatty degeneration of the kidney as in the desquamative inflammatory diseases before alluded to, will be manifest from a perusal of the second part of this article.

In this form of simple fatty degeneration of the kidney, all the tubes become almost uniformly distended with oil. In a slight degree, and in the earlier stages, it is often found after death in cases where there is no reason to suspect that it has been productive of serious mischief during life: it is not until the fatty degeneration exceeds a certain degree that the functions of the organ become seriously affected. It is this form of fatty degeneration which frequently occurs in animals, as a consequence of their confinement in a dark room, a fact which was first noticed by Mr. Simon.*

The second form of fatty degeneration of the kidney differs from the first in having combined with it more or less of the changes characteristic of desquamative nephritis. The cortical portion of the kidney is soft and pale, and interspersed with numerous small yellow opaque specks. The kidney is generally enlarged; sometimes it is even double the natural size. In some cases the cortical portion is somewhat atrophied and granular; but neither in this nor in the first form of fatty degeneration of the kidney does that extreme wasting with granulation occur, which is so frequent a consequence of chronic nephritis. On a microscopical examination the convoluted tubes are found filled in different degrees with oil, some tubes being quite free, while others are ruptured by the great accumulation in their interior. The opaque yellow spots scattered throughout the cortical portion are neither more nor less than convoluted tubes distended, and many of them ruptured by their accumulated fatty contents. The cells which contain the oil are for the most part smaller, more transparent, and less irregular in their outline than the ordinary healthy epithelium; they are increased in number, and many of them are so distended with oil as to appear quite black. In parts of the same kidney there may commonly be seen some of the appearances already described as characteristic of desquamative nephritis. This form of disease is very commonly associated with fatty degeneration of the liver, but less frequently so than the first form of fatty degeneration of the kidney.

The condition of urine connected with this form of renal degeneration is usually as follows: — The quantity is small, the sp. gr. rather above than below the healthy standard; it is generally very albuminous, and sometimes bloody. On a microscopical examination of the sediment which is deposited after standing for a few hours in a conical glass, there may be seen the fibrinous moulds of the tubes so often alluded to, frequently entangling blood corpuscles and epithelium. But the main point to be attended to is this, that many of the epithelial cells are more or less distended with oil. (See *figs.* 149 and 164.) This fatty condition of the epithelium indicates with certainty the existence of one of the most serious and intractable diseases to which the kidney is liable. The majority of the cases of acute desquamative nephritis, and many of the chronic cases, end in complete recovery; but fatty degeneration of the kidney almost invariably leads to general dropsy and

* Med. Chir. Trans. vol. xxix.

a fatal termination. It is therefore as important to distinguish between acute or chronic nephritis and fatty degeneration of the kidney as it is to distinguish acute pneumonia or chronic bronchitis from tubercular disease of the lung ; and the diagnosis of the renal disease may be made with as much ease and certainty by a microscopical examination of the urine as that of the pulmonary disease by auscultation and percussion of the chest.

The three forms of disease just alluded to, viz. acute and chronic desquamative nephritis, and fatty degeneration of the kidney, include the greater number of those cases to which the term "Bright's disease" is commonly applied.

On an inspection of the plates in the 1st vol. of Dr. Bright's well known Medical Reports, it is evident that more than one form of disease is there described by that distinguished physician. In a paper published two years since*, I maintained that the term Bright's disease should be confined to those cases in which there is fatty degeneration of the kidney, but after a further consideration of the subject, I am of opinion that if the expression "Bright's disease" is retained it should be used only as a generic term to include several diseases, the existence and the importance of which were first made known by Dr. Bright. In order to convey a precise idea of the particular form of Bright's disease alluded to, it is clearly necessary to use some terms having a more definite meaning, and I have suggested some which appear sufficiently expressive for the purpose.

Hydatids are occasionally found in the kidney. Dr. Baillie† was well aware of the distinction between true hydatid cysts as they are found in the kidney and the more common serous cysts, which he correctly supposed to arise from an expansion of some of the natural tissues of the kidney. He mentions one case of hydatids in the kidney, in which there was a discharge of these bodes with the urine. It is probable that in every case of hydatid disease of the kidney, the nature of the affection might be ascertained by a careful examination of the urine. I have already stated that if Mr. Simon's account of the common serous cysts were a correct one, they would be in fact hydatid cysts, and as they would continually escape with the urine, they might be detected by a microscopical examination of the liquid. Assuming, however, that they are dilatations of the tubes, it is not surprising that they should never be found in the urine, and that they cannot be dissected out from the kidney after death.

Cancer of the kidney is less uncommon than it was formerly supposed to be. It is rarely limited to the kidney, and in the great majority of cases, where other parts are implicated, the disease has obviously originated in some one or other of these parts.‡ Cancer less frequently affects the bladder and kidney simultaneously than might be expected. M. Rayer and Dr. Walshe have observed the frequent co-existence of cancer of the liver and right kidney, and of the adjacent parts of the stomach on the descending colon and the left kidney.

In thirty-six of the cases collected by Dr. Walshe, the anatomical state is described with considerable accuracy. "In thirty-one of these, pure encephaloid or one of its varities, was the species of cancer observed ; scirrhus in five only, — two of them of doubtful character; while colloid did not, in any instance, occur in this situation. Encephaloid exhibits itself in all degrees of consistence, and in several of its varieties. Among these varieties, the hæmatoid may almost be considered frequent, as compared with its rarity in other internal organs. Encephaloid occurs in the infiltrated and tuberous forms; the former more especially when the disease is primary, the latter when secondary. Cancerous infiltration (as organic diseases generally) commences in the cortical substance. This structure may, in some instances, disappear altogether under the influence of the accumulating cancerous matter, without the tubular substances having suffered in the least. The nodular form of the affection likewise originates in the cortical substance, generally near the surface ; as the masses enlarge, they become prominent on the surface, and assume the appearance of having formed between the surface of the kidney and its capsule." The renal tissue between the cancerous masses is sometimes quite healthy; but in other instances it is congested, inflamed, or actually in a state of suppuration, the pus being infiltrated or accumulated in a single spot. Melanotic discolouration of the cancerous masses is occasionally, but rarely, witnessed in the kidney. In thirty-five cases of renal cancer, the disease affected both organs sixteen times; the right alone thirteen times, the left alone six.*

In concluding this brief sketch of the pathology of the kidney, I will venture to predict that, within a very short space of time, the diseases of the kidney will be more completely and generally understood with reference to their pathology, diagnosis and treatment than those of any other organ. There are two circumstances which justify such an anticipation :—1. There is perhaps no important organ in the body whose minute structure has been so completely and so clearly demonstrated as that of the kidney has been by Mr. Bowman. And 2nd, The morbid deposits or accumulations to which the kidney is liable occur, almost without exception, in such a situation, within the uriniferous tubes, that portions of these materials are being continually washed out by the stream of liquid which is poured into the extremities of the tubes, and so they come within the sphere of our daily obser-

* Med. Chir. Trans. vol. xxix.

† The Morbid Anatomy of the Human Body. By Matthew Baillie, M.D.

‡ The Nature and Treatment of Cancer. By Walter Hayle Walshe, M.D.

* Dr. Walshe. Op. cit.

vation; thus affording the pathologist and the practitioner an opportunity of ascertaining the nature and tracing the progress of disease which is not presented in the case of any other internal organ.

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On the subject of the Development of the Kidney reference may be made to the article OVUM.

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REPTILIA. — A very extensive and important class of vertebrate animals, intermediate in their organization and general economy between fishes and the warm-blooded, air-breathing birds and quadrupeds, from both of which reptiles are distinguished by the following characters*: —

Reptiles have the heart disposed in such a manner, that, on each contraction, it sends to the lungs only a portion of the blood which it has received from the various parts of the body, and the rest of that fluid returns to the several parts without having undergone the action of respiration.

From this it results, that the oxygen acts on a less portion of the blood than in the mammifera. If the quantity of respiration in the latter animals, in which the whole of the blood passes through the lungs before returning to the parts, be expressed by unity, the quantity of respiration in the reptiles must be expressed by a fraction of unity.

In consequence of this low degree of respiration, reptiles have cold blood, and their muscular power is less than that of quadrupeds, and, *à fortiori*, than that of birds. Accordingly, they do not often perform any movements, but those of creeping and of swimming; and though many of them leap, and run fast enough on some occasions, their general habits are lazy, their digestion slow, their sensations not acute, and in cold and temperate climates they pass almost the entire winter in a state of lethargy. Their muscles preserve their irritability much longer than in the higher classes. Their heart will beat for several hours after it has been plucked out, and its loss does not hinder the body from moving for a long time. In many of them, it has been observed that the cerebellum is remarkably small, which perfectly accords with their little propensity to motion.

Reptiles are provided with a trachea and larynx, though the faculty of an audible voice is not accorded to all of them. Not possessing warm blood, they have no occasion for integuments capable of retaining the heat, and they are covered with scales, or simply with a naked skin.

The females have a double ovary, and two oviducts. The males of many genera have a forked or double organ of intromission.

Reptiles do not sit upon their eggs; hence the latter have generally only a membranous envelope. In many of the reptiles which lay eggs, especially in the colubri, the young one is already formed, and considerably advanced in the egg at the moment when the mother lays it; and it is the same with those species which may, at pleasure, be rendered viviparous by retarding their laying.

The quantity of respiration in reptiles is not fixed, like that of mammifera and birds,

* Cuvier, Règne Animal, t. ii.

but varies with the proportion which the diameter of the pulmonary artery bears to that of the aorta. From this proceed differences of energy and sensibility much greater than can exist between one mammiferous animal and another, or one bird and another.

Accordingly, the reptiles exhibit forms, movements, and properties much more various than the two preceding classes; and it is more especially in their production that nature seems to have sported in the formation of fantastic shapes, and to have modified in all possible ways the general plan which she has followed for vertebrated animals.

The comparison of their quantity of respiration and their organs of motion has, however, given foundation for their separation into three distinct orders, viz.:—

1st, The CHELONIANS, or TORTOISES (Chelonia), in which the body, supported on four legs, is enveloped by two plates or shields, formed by the ribs and the sternum.

2d, The SAURIANS, or LIZARDS (Sauria), in which the body, supported on four or on two feet, is covered with scales.

3d, The OPHIDIANS, or SERPENTS (Ophidia), in which the body is always destitute of limbs.

ORDER I. CHELONIA.

Family 1.— TESTUDINIDÆ.

Testudo (Land Tortoise), Emys (Freshwater Tortoise), Chelonia (Turtle), Chelys, Trionyx.

ORDER II. SAURIA.*

Family 1.— CROCODILIDÆ.

Gavial, Crocodilus, Alligator.

Family 2.— LACERTIDÆ.

Monitor, Crocodilurus, Tupinambis, Ameiva, Lacerta, Algyra, Tachydromus.

Family 3.— IGUANIDÆ.

Stellio, *Cordylus*, *Stellio*, *Doryphorus*, *Uromastix*, Agama, *Agama*, *Tapayes*, *Trapelus*, *Leiolepis*, *Tropidolepis*, *Leposoma*, *Calotes*, *Lophyrus*, *Gonocephalus*, *Lyriocephalus*, *Brachylophus*, *Physignathus*, Istiurus, Draco, *Sitana*, Iguana, Ophryessa, Basiliscus, Polychrus, Ecphimotes, Oplurus, Anolius.

Family 4.— GECKOTIDÆ.

Gecko, *Platydactylus*, *Hemidactylus*, *Thecadactylus*, *Ptyodactylus*, *Spheriodactylus*, *Stenodactylus*, *Gymnodactylus*, *Phyllurus*.

Family 5.— CHAMÆLEONIDÆ.

Chamæleo.

Family 6.— SCINCIDÆ.

Scincus, Seps, Bipes, Chalcides, Chirotes.

ORDER III. OPHIDIA.†

Family 1.— ANGUIDÆ.

Anguis, *Pseudopus*, *Ophisaurus*, *Anguis*, *Acontias*.

* σαῦρος, a lizard.
† ὄφις, a serpent.

Family 2.— SERPENTIDÆ.

Amphisbæna, Typhlops, Tortrix, Boa *Scytalus*, *Eryx*, *Erpeton*, Coluber, *Python*, *Cerberus*, *Xenopeltis*, *Heterodon*, *Hurria*, *Dipsas*, *Dendrophis*, *Dryinus*, *Dryophys*, *Oligodon*, Acrochordus, Crotalus, Trigonocephalus, Vipera, *Naia*, *Elaps*, *Micrurus*, *Platurus*, *Trimeresurus*, *Oplocephalus*, *Acanthophis*, *Echis*, *Langaha*, *Bongarus*, Hydrus, *Hydrophis*, *Pelamides*, *Chersydrus*.

Family 3.— CÆCILIADÆ.

Cæcilia.

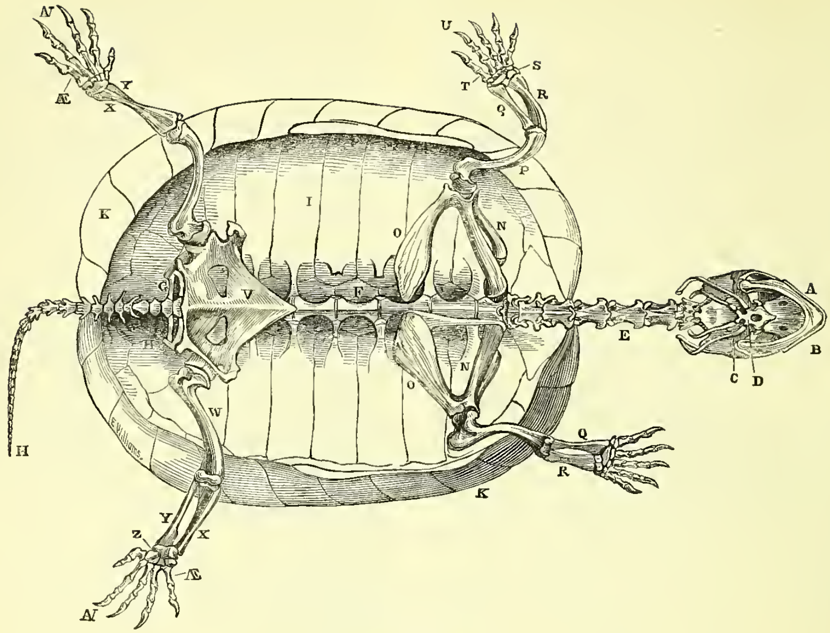
Osteology.— The Chelonian reptiles are distinguished from all other vertebrata by the peculiar construction of their skeleton; the bones of the thorax being in these remarkable animals literally placed externally so as to form a suit of armour that encloses the muscles as well as the viscera, and within which the bones both of the shoulder and of the pelvis are lodged. The greater part of the dorsal shield or *carapax* is formed by eight pairs of ribs (*fig.* 177, I) united to each other towards the mesial line by a longitudinal series of angular plates, which are in fact the spinous processes (*neural spines*) of as many vertebræ spread out horizontally. The ribs are connected by suture to the margins of these plates, and likewise to each other, either along their whole length, or to a greater or less extent, according to the species or the age of the animal.

In front of the carapax there are eight vertebræ which do not enter into its composition (*fig.* 177, E): of these the seven anterior ones, which are ordinary cervical vertebræ, are quite free in their movements. The eighth vertebra, which may be called the first dorsal, is placed obliquely between the last moveable cervical and the first vertebra entering into the composition of the carapax; posteriorly this vertebra (the eighth) has its spinous process somewhat elongated and slightly enlarged, for the purpose of its attachment by synchondrosis to a tubercle that is situated upon the lower surface of the first of the series of the mesian plates of the carapax.

The ribs which, by their external broad plates, enter into the composition of the carapax, give off from their inferior surfaces a process which corresponds with what in ordinary skeletons is called the head of the rib. This process is always connected with the spine between the bodies of two contiguous vertebræ, as are the heads of the ribs in other animals; and, carrying out the comparison, that part of the ribs which articulates by suture with the median plate may be regarded as the "tubercle," only here it is connected with the expanded spinous process instead of the transverse.

In the Turtles the ribs are not united to each other throughout their whole length; towards their external extremities there only remains the narrow central portion, the intervals between the contiguous ribs being in this

Fig. 177.



Skeleton of Tortoise.

A, superior maxilla; B, inferior maxilla; C, ossiculum auditus; D, os hyoides; E, cervical vertebræ; F, dorsal vertebræ; G, sacrum; H, caudal vertebræ; I, dorsal ribs; K, marginal scales; N, scapula; O, coracoid bone; P, os humeri; Q, radius; R, ulna; S, bones of the carpus; T, metacarpal bones; U, digital phalanges; V, pelvis; W, femur; X, tibia; Y, fibula; Z, tarsus; Æ, metatarsus; A.V., phalanges of the foot.

case filled up with a cartilaginous membrane. In the carapax of fresh-water tortoises (Emys), and in the Chelides, the interspaces between the ribs in time become completely filled up, and the ribs are connected by suture, throughout their whole extent, to each other and to the marginal pieces (K).

The marginal pieces (*fig.* 177, P) form a sort of osseous frame composed of a series of bones, eleven in number on each side, which are united together by suture, and likewise connected with the extremities of the ribs. In the Tortoises this connection with the ribs is effected by suture, but in the Turtles and other genera having the extremities of the ribs narrow, their apices are implanted in fossæ excavated in the marginal plates, where they are fixed by a species of synchondrosis.

These marginal plates cannot be otherwise regarded than as the representatives of the sternal ribs of the Crocodiles and other Saurians; the two first and the two last, like the abdominal ribs of the Crocodile, being developed without the presence of any dorsal ribs in correspondence with them. In the Soft-Tortoises (Trionyx) the marginal pieces are never ossified, but are represented by a cartilaginous rim, in which sometimes osseous particles are sparingly deposited.

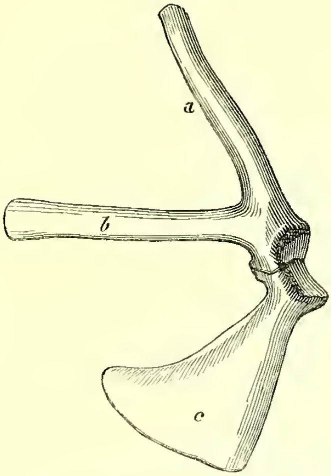
The ventral cuirass of the Chelonian reptiles, called the *plastrum*, is exclusively formed by the sternum, which in this race of animals seems to attain its maximum of development. It consists invariably of nine pieces, eight of which are pairs; while the ninth, situated between the four anterior ones, is central and azygos.

These elements of the sternum have been well-named by Geoffroy St. Hilaire in accordance with the situations that they occupy. The anterior pair are the *episternal* pieces, and the pair situated behind these the *hyo-sternals.* In the centre bounded by the above four bones is the azygos piece named the *ento-sternal.* The pair situated immediately posterior to the hyosternal are called the *hypo-sternal* pieces, and the two which terminate the plastrum *xipho-sternals.* The sacral and caudal vertebræ return to the usual arrangement, being all free and moveable, having their bodies concave in front and convex behind, and their apophyses as in ordinary vertebræ. Their number varies in different species from eight to twenty-seven.

The scapular apparatus is contained in the interior of the thoracic cavity. It consists of a remarkably shaped three-branched bone (*fig.* 178.), which is suspended on each side by a ligamentous attachment beneath the second vertebra of the carapax. The branch which is thus suspended (*a*), notwithstanding its strange position inside the thorax, is the *scapula;* the branch *b* Cuvier, after the maturest deliberation, decided to be its acromion process; while the flattened bone *c* directed backwards, he considers as being incontestably the coracoid bone. This three-branched shoulder, with its almost cylindrical scapula,

and an acromion process that almost equals it in size, is quite peculiar to the Chelonian rep-

Fig. 178.



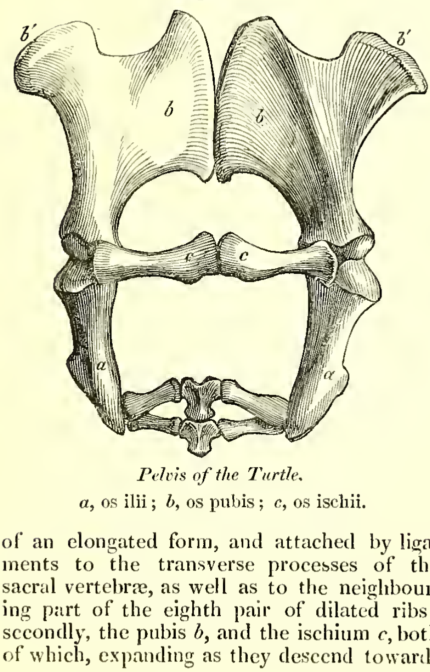
Scapular Apparatus of Chelys.

a, scapula; *b*, acromion process; *c*, coracoid bone.

tiles, nothing like it existing in any other vertebrate animals: nevertheless, the relations of these bones, and the muscles derived from them, prove clearly enough their identity, and allow of strict comparison with those of other races of vertebrata.

The *pelvis* is always composed of three distinct bones on each side, which contribute, as in quadrupeds, to the formation of the cotyloid cavity, viz. the ilium (*fig.* 179, *a.*), which is

Fig. 179.



Pelvis of the Turtle.

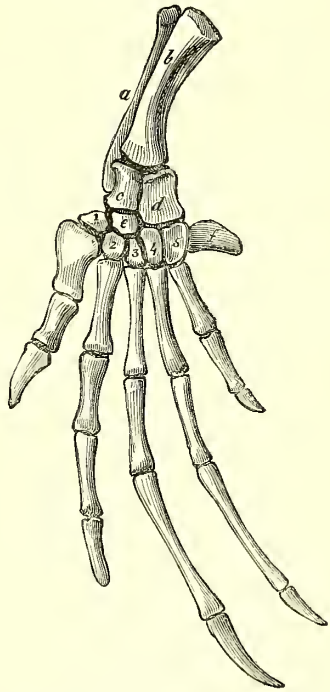
a, os ilii; *b*, os pubis; *c*, os ischii.

of an elongated form, and attached by ligaments to the transverse processes of the sacral vertebræ, as well as to the neighbouring part of the eighth pair of dilated ribs: secondly, the pubis *b*, and the ischium *c*, both of which, expanding as they descend towards the plastrum, terminate by joining their fellows of the opposite side.

The cylindrical bones of the extremities resemble those of other four-footed reptiles, and present no peculiarity worthy of special notice, except in a geological point of view.

In the turtles, all the bones of the carpus are flattened, and of a squarish form. In the first row there are two bones (*fig.* 180, *c*, *d.*) con-

Fig. 180.



Anterior extremity of a Turtle. (*After Cuvier.*)

nected with the ulna; and in the second row there are five smaller ones (1, 2, 3, 4, 5.), to which are appended the five metacarpal bones. In addition to the above, there is an intermediate bone (*e*), situated beneath the ulnar carpal bone (*c*), and above the second and third bones of the last row, (2, 3.) This piece, Cuvier thinks, corresponds with the dismembered portion of the trapezoid bone, met with in monkeys. Lastly, there is a great crescent-shaped bone (*f*), which is adherent to the ulnar margin of the piece which supports the metacarpal bone of the little finger; this is the os pisiforme, although its situation is so low down.

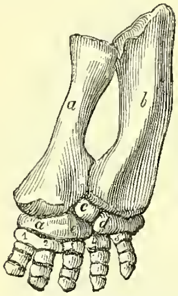
Between the bone (1), which supports the metacarpal bone of the thumb, and the radius (*a*), the connexion during a long period is effected entirely by ligaments, without any appearance of the great scaphoido-semilunar bone which exists in the other sub-genera, but with age a small ossicle makes its appearance in this situation. In very large individuals, the two antepenultimate bones of the second row are consolidated into one.

The metacarpal bone of the thumb is

short and broad; the others are all long and slender. The little finger has only two phalanges, and is not longer than the thumb, so that the whole hand has a pointed shape. The thumb and the index finger only have their last phalanx armed with a nail.

In the land tortoises (*fig.* 181.), it is neces-

Fig. 181.



Anterior extremity of the Tortoise.

sary to admit that there are only two phalanges to each finger, or else to suppose, either that the last row of carpal bones is wanting, or that the metacarpal bones are deficient. By comparison, however, with the hands of fresh-water tortoises, it is evident that the bones present belong to the carpus and metacarpus.

This being allowed, the carpus is found to consist of a large radial or scaphoido-semilunar bone (a'), of two ulnar bones (c, d.), which are nearly of a square shape, of five bones of the second row (1, 2, 3, 4, 5,) supporting the metacarpal bones, and of an intermediate bone (e), situated between the great radial (a'), the first cubital, and those which support the third and fourth metacarpal bones. This intermediate bone is very frequently consolidated with the great scaphoido-semilunar bone, as represented in the figure.

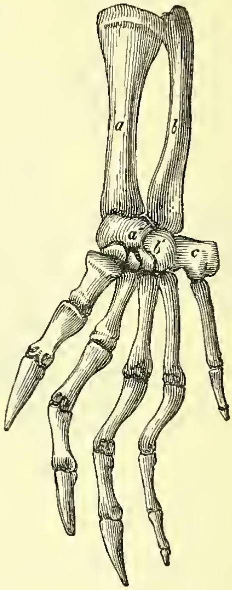
The bones of the metacarpus in these tortoises are even shorter than the phalanges.

Hind Feet. — In the Chelonians, the os calcis does not project posteriorly, so that the tarsus is as flat as the carpus. In the turtles (*fig.* 182.), it is composed of six or seven bones, according as the last is reckoned as belonging to the tarsus or to the little toe. Two constitute the first row, of which the larger (a'), which is nearly of a rhomboidal shape, and connected both to the tibia and fibula, is the *astragalus;* the smaller (b), connected to the fibula alone, is the only representative of the os calcis.

In the second row there are four pieces, three of which are cuneiform bones, supporting the metacarpal bones of the great toe, and of the two following ones; and the fourth, which is of larger size, appropriated to the two last metatarsals.

The metatarsal bones of the great toe and of the little toe are singularly broad and flat; indeed, that of the little toe (c) might be taken for one of the tarsal bones a little removed from its place, in which last case the little toe would consist of only two phalanges: according to the former supposition it would have three like the middle ones. The thumb or great toe has but two; it is furnished with

Fig. 182.

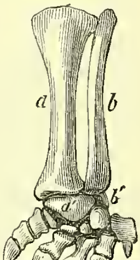


Hind-foot of Trionyx.

a nail at its extremity, as well as the finger which is next it; the two following have their terminal phalanges large but without nails; the last phalanx of the little toe is very small.

In the land-tortoises the analogue of the

Fig. 183.



Hind-leg of Tortoise.

astragalus is more bulky and thicker, whilst the fibular bone or analogue of the os calcis is proportionally smaller. The other four tarsal bones are present, and in this case that which supports the little finger seems to form one of the series, both from its position and its shape; sometimes it supports a rudiment of a little toe consisting of one piece only, but in many species this is wanting.

The metatarsal bone of the great toe is short but not flattened; the others are a little longer: none of the four toes have more than two phalanges.

In the Chelonian reptiles, the os hyoides varies very remarkably as to its form in

different genera, and even in different species. It generally consists of a body or centrum, which is sometimes itself divided into several pieces, and of two and sometimes three pairs of cornua ; also under the anterior part of its body there is suspended a bone or a cartilage (sometimes double) which is the special bone of the tongue, the analogue of the lingual bone of birds, only in them it is articulated in front of the body of the hyoid bone, whilst in the Chelonians it is suspended underneath.

The greater *cornua* (the anterior pair, when only two pairs are present, the middle pair when there are three, that which represents the styloid bones) embrace the œsophagus, and mount up behind those muscles which represent the digastric or depressors of the lower jaw, but without being attached otherwise than by their own muscles.

In Trionyx, the body of the os hyoides, is composed anteriorly of a cartilaginous point, beneath which is suspended a large lingual cartilage of an oval form. At the base of each pointed cartilage there is attached an osseous piece of a rhomboidal shape, which represents the anterior cornua; behind this are four other pieces, forming a disc, which is concave superiorly, broadest in front, and deeply notched both posteriorly and on each side. To the anterior angles of this disc are appended the middle cornua and to the posterior the posterior cornua. All four of these eornua are considerably ossified. The middle cornua consist of one long piece, which is eompressed, of an arched form, and terminated by a little cartilage. The other cornua are broader and flatter ; they are eked out by a cartilage, in the thickness of which are enclosed five or six osseous nuclei, all placed in a line with each other, each of a round or oval form, and quite hard and distinct, so that the os hyoides of this reptile seems to consist of twenty different osseous pieces, which apparently remain distinct through life.

The hyoid apparatus of Chelys is equally remarkable. Its body is composed of a single long narrow piece, of a prismatic shape, hollowed above into a canal in which the trachea is lodged. Anteriorly, this central portion expands in order to sustain two additional pieces on each side, four in all, without reckoning the centrum itself. The two middle ones unite in front, leaving a space between themselves and the principal body, which is closed by a membrane upon which the larynx reposes.

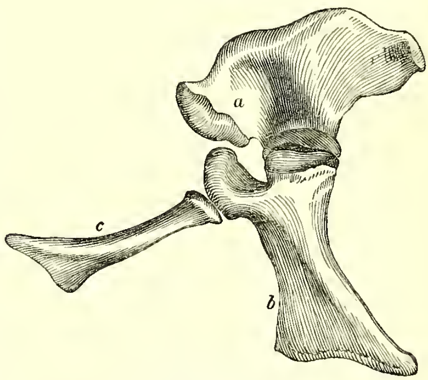
The two lateral pieces perhaps represent the anterior cornua ; it is at the dilatation that they form with the expanded portion of the centrum that the middle cornua are articulated : these are very strong and prismatie for the internal half of their course ; afterwards slender ; and they give attachment externally to an additional piece, which is distinct from the rest of the cornua.

The posterior cornua are articulated to the posterior extremity of the prismatic portion of the centrum; they are long, slightly compressed, and eurved. Under the anterior and dilated portion is suspended the lingual bone, which consists anteriorly of a semicircular cartilage, and behind of two crescent-shaped osseous pieces, the inner angle of which is prolonged into a kind of tail or pedicle that passes beneath the prismatic body of the hyoid bone.

In the turtles, the body of the hyoid resembles an oblong shield, eoncave upon its upper surface for the sake of lodging the larynx and the commencement of the trachea ; pointed in front, where it forms part of the tongue, laying above the lingual bone. The anterior cornua are very small ; the great cornua are articulated to the middle of its lateral margin, and have at their free terminations additional cartilaginous pieces. The posterior cornua are attached to the posterior angles.

The pelvis of lizards (*fig.* 184.) is composed

Fig. 184.



Pelvis of Crocodile.

a, ileum ; *b*, ischium ; *c*, pubis.

of three bones, which, as in quadrupeds, assist in the construction of the colyloid cavity. The *os ilii* (*a*) occupies the upper half; its neck is broad and short, and its spinous portion, instead of running forwards, as in mammifers, or being rounded, as in the crocodile, is directed obliquely backwards, in the shape of a narrow band.

Inferiorly, the *pubis* (*b*) and the *ischium* (*c*) are conjoined with their fellows of the opposite side along the mesial line ; but the pubis does not unite with the ischium, and consequently the two infra-pubie foramina are only separated from each other by a ligament.

The pelvis of the different genera of lizards are prineipally distinguished from each other by the symphysis of the pubic bones, which in the monitors is formed by the junction of two broad truncated surfaces ; but in most other genera by a much less extensive union. The junction between the ossa ischii is always effected by a wide surface.

The chameleon differs from all other lizards in having the ossa ilii straight, and directed almost perpendicularly upwards, to be attached to the spine. They are likewise re-

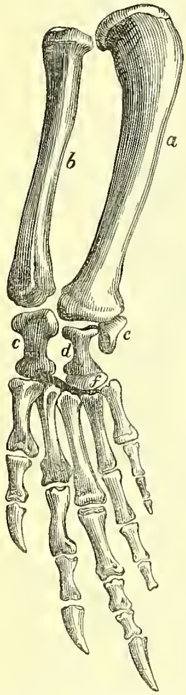
markable, because they terminate in a triangular cartilage, analogous to that which ekes out the scapula.

Vestiges of the pelvis may be traced in *Ophisaurus* and *Anguis*, under the shape of a little os ilii, with a vestige of the ischium, but without any symphysis.

The cylindrical bones of the anterior and posterior extremities present nothing worthy of special remark.

The *carpus* (*fig.* 185.) consists of nine bones, the disposition of which is not unlike that of the carpal bones of a monkey. In the first row there is a radial bone (*c*), a cubital (*d*),

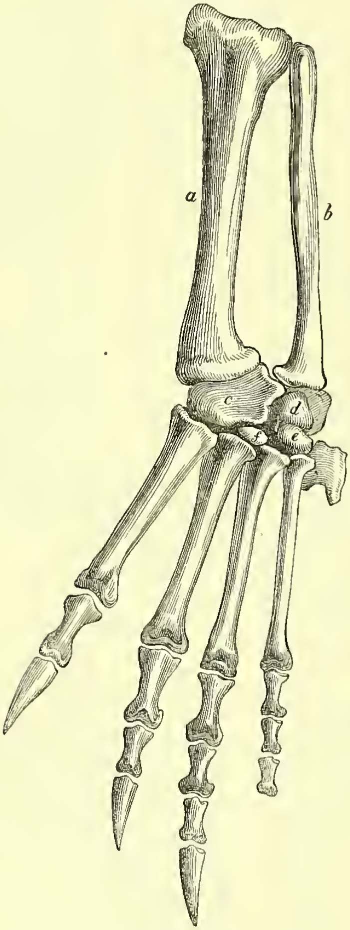
Fig. 185.



Fore-leg of Crocodile.

a, the ulna; *b*, the radius; *c*, radial carpal bone; *d*, ulnar carpal bone; *e*, os pisiforme; *f*, a lenticular bone interposed between the ulnar carpal bone and the metacarpal bones of the three inner fingers.

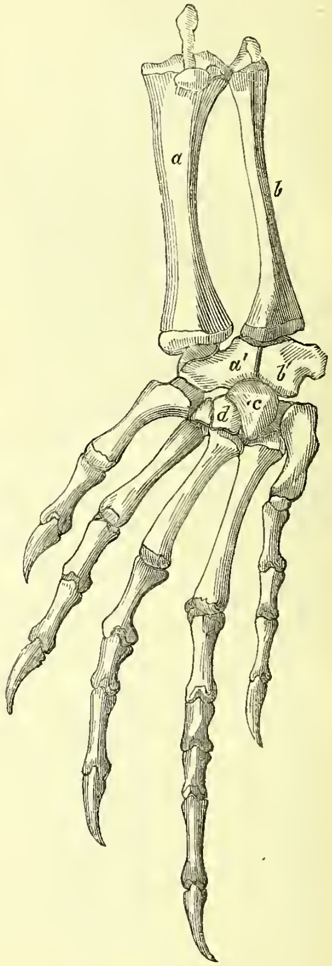
Fig. 186.



Hind-leg of Crocodile.

a, the tibia; *b*, the fibula; *c*, the astragalus; *d*, the os calcis; *e*, the os cuboides; *f*, the cuneiforme, there is a flattened triangular supernumerary bone attached to the outer side of the cuboid, which in the figure has no letter of reference.

Fig. 187.



Tarsus of Lizard.

a, the tibia; *b*, the fibula; *a'*, the astragalus; *b'*, the os calcis; *c*, the os cuboides; *d*, the cuneiforme.

which is of large size, and an os pisiforme (*e*) attached to the inferior extremity of the ulna. In the second row there are five small bones arranged in a curvilinear form, and corresponding with the five metatarsal bones: the ninth (*f*) is interposed between the two large bones of the first row, and the first, second, third, and fourth of the second, forming a kind of central piece to the carpus.

The *tarsus* of lizards, like that of the crocodile, is composed of four bones only.

The first row consists of two: one tibial (*fig.* 187, *a'*), which is likewise slightly articulated with the fibula; the other fibular (*b*), of smaller dimensions, which, however, soon unites into a single piece with the former, situated on the same plane.

The second row likewise consists of two

bones, the larger of which (*c*) supports the metatarsals of the fourth and fifth toes, whilst the smaller (*d*) is situated between the preceding and the metatarsal bones of the second and third toes. This latter is also slightly connected with the astragalus, which alone supports the metatarsal bone of the internal or representative of the great toe.

The four first metatarsal bones are slender and nearly straight, becoming progressively longer as far as the fourth. The fifth is short, wide, and curved superiorly towards the larger of the two bones of the second row (*e*), to the side of which it is articulated.

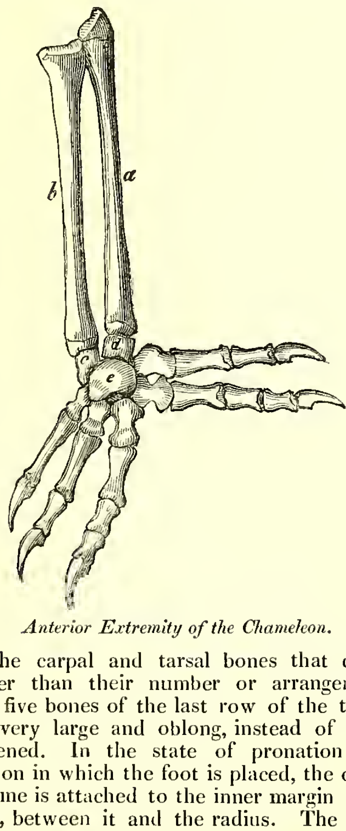
The thumb or internal toe consists of two phalanges, the second of three, the third of four, and the fourth of five ; this is the longest toe in the foot of a lizard, giving to it the peculiar elongated and unequal form by which it is immediately distinguished. The fifth toe, although almost as short as the first, is composed of four phalanges.

The ungueal phalanges of all the toes are sharp, hooked, and pointed.

The above description, with slight differences as to the proportions, is applicable to all those subgenera of lizards which have their limbs fully developed, with the exception of the Chameleons and certain Geckos.

Even in the chameleon it is the proportions

Fig. 188.

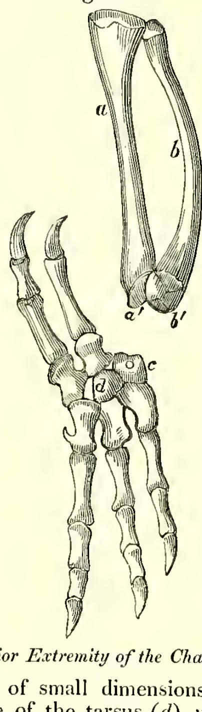


Anterior Extremity of the Chameleon.

of the carpal and tarsal bones that differ, rather than their number or arrangement. The five bones of the last row of the tarsus are very large and oblong, instead of being flattened. In the state of pronation and torsion in which the foot is placed, the os pisiforme is attached to the inner margin ofthe ulna, between it and the radius. The ulnar carpal bone (*fig* 188, *d*) and the radial (*c*) are small, the central bone (*e*) being the largest of all, and around this the five carpal bones of the last row are arranged like the spokes of a wheel. These five bones are longer than in ordinary lizards, and in fact represent the metacarpal bones as well as the last row of the carpus, leaving the fingers possessed of their proper number of phalanges. This remarkable arrangement permits the foot of the chameleon to be, as it were, split into two divisions. The thumb, the index, and the middle finger are connected by the skin into one group, which is turned inwards, while the two remaining fingers, similarly encased, are turned outwards, thus enabling this remarkable reptile to grasp firmly the boughs among which it lives by a mechanism very similar to that of the foot of a parrot or other scansorial bird.

In the tarsus of the chameleon the mechanism is very similar. The tibial tarsal bone (*fig*. 189, *a′*.) and the fibular tarsal bone (*b′*)

Fig. 189.



Posterior Extremity of the Chameleon.

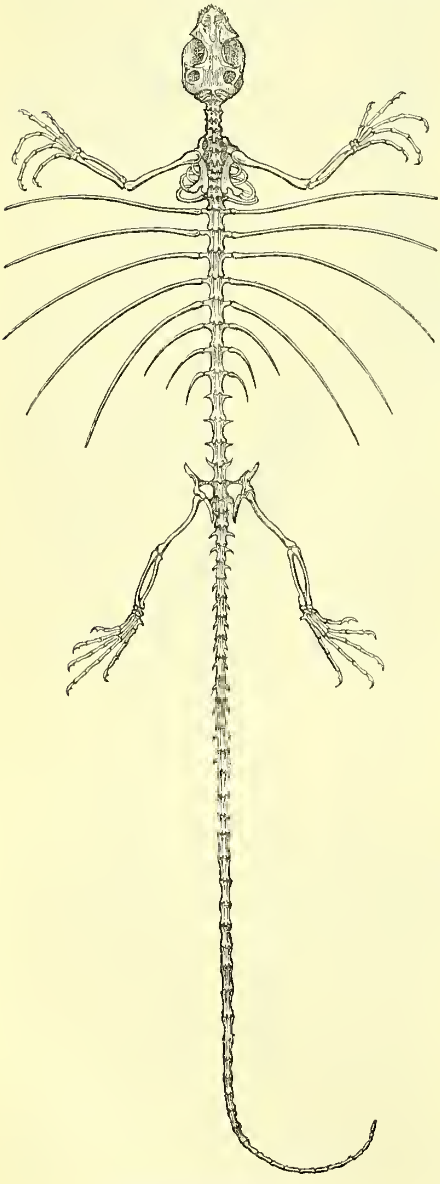
are equally of small dimensions, whilst the central bone of the tarsus (*d*), which articulates with both the above, is of a spherical form, and serves as a pivot for the movements of the foot. It has another bone (*c*) attached to its outer side, and the rest of its circumference is occupied by the attachments of the five metatarsal bones, the shape of which resembles precisely that of the corresponding bones in the hand; and in like manner they most probably represent the last row of the tarsal bones of ordinary lizards conjoined with those of the metatarsus. This being allowed to be the case, the thumb-finger of the chameleon consists of two phalanges, the first finger of three, the second

and the third of four, and the fourth of three, the same as in the hands.

It was an observation made as far back as the time of Aristotle, that the division of the anterior and of the posterior feet of the chameleon is effected in an inverse manner, the latter having the thumb and first finger only conjoined and turned inwards, but the other three turned outwards, whilst, as has been stated above, the anterior limb has three turned inwards and only two turned outwards,—a beautiful provision for ensuring the steadiness of the creature's grasp.

The dragon (*Draco*) possesses fourteen pair

Fig. 190.



Skeleton of Draco volans.

of ribs, viz., six genuine, short, and curved ribs, which reach the breast-bone, and eight pairs of false straight ribs, which are seated in the wing membrane, and support the same. The posterior extremity of the ribs has a little head, in which there is a small socket of articulation, which is merely inserted upon the spherical articulating surface on the point of the transverse processes, and not at all into the bodies of the vertebræ. Owing to this remarkable mode of insertion, a very free joint is produced, enabling the ribs (especially those that are implanted in the wing membrane) to move forwards and backwards, and upwards and downwards, in different directions. Of the genuine ribs, the anterior ones are the shortest, and the posterior ones the longest; they all terminate in a cartilaginous point, which attaches itself to the breast-bone. Of the eight pairs of false ribs, the five first pairs are very long, and the three following pairs are short, especially the two last pairs, which cannot be seen at all in the wing membrane. The false ribs become gradually thinner, and terminate at the edge of the wing membrane, in very fine cartilaginous points. In the whole animal kingdom, it is the dragon alone that exhibits this isolated and most remarkable structure. The wing membrane of the dragon distinguishes itself from the wing membrane of the flying squirrel by the circumstance of being supported by the ribs, which is not the case in the latter animals: the same circumstance likewise distinguishes their wing membrane from that of the bat, in which the prolonged anterior extremities, particularly those bones which are analogous to the finger joints, are continued into the wing.

The ribs, when flying, are moved by several muscles. Strong triangular muscles spring laterally from the bodies of the dorsal vertebræ, and are inserted into the lower edge of the commencing part of the false ribs. These muscles move the ribs, when flying, together with the wing membrane, downwards and slightly backwards. Other broad muscles, which have their source at the upper surface of the vertebræ, and which attach themselves to the ribs, move the ribs with the wing membrane. The alternating contractions and expansions of these muscles effect the fluttering or flying of the dragons. Thin muscles are likewise seated between the ribs, analogous to the intercostal muscles.

Osteology of Ophidians.— In the true serpents, the vetebral column itself constitutes the principal portion of the skeleton, and the number of pieces of which it consists is sometimes prodigious, varying in different species, from about a hundred (*Acontias*) up to three hundred (*Boa*) or even four hundred (*Python*) distinct vertebræ. These have pretty much the same shape throughout the whole length of the spinal column, each presenting the centrum or body, and the spinous, transverse, and articulating processes forming the bonds of connexion between them, or the levers by which they are wielded.

The bodies of contiguous vertebræ are

connected together by very perfectly constructed ball and socket joints, each vertebra presenting a concavity in front, and a convex ball upon its posterior aspect; the plane of the circumference of the articulating surface being oblique from before to behind.

The spinous apophyses are generally elongated and flattened, being prolonged posteriorly to the articular apophyses, which they partially overlap.

The articulating processes are of two sorts; some facing outwardly, represent ordinary articulating apophyses, with horizontal facets. The second face inwards, and are situated at the base of the spinous process. These apophyses are so arranged, that, as in the lumbar vertebræ of some Edentata amongst quadrupeds, two vertebræ are articulated together by a double tenon received into a double mortice, the only difference being, that the facets of the upper tenon and mortice are continuous, and form with each other an acute angle.

The articular facets, without including those of the bodies, are twelve in number for each vertebra; an arrangement which restricts the vertical movements of the spine very materially, whilst at the same time it permits very free motion in a horizontal direction.

The transverse processes are very short and scarcely perceptible, except by a tubercle, which offers two facets for articulation with the ribs. In the caudal vertebræ, however, the transverse processes are much longer, and inclined downwards; they are even double towards the anterior part of the caudal region.

In almost all serpents, the body of the vertebræ presents inferiorly a prominent longitudinal crest, which very generally terminates behind in a prominent spine, that is directed more or less towards the tail. In some genera, as in *Crotalus*, for example, this spine is even longer than the superior spinous process, and moreover is very frequently double.

The arrangement of the articular processes described above is not met with in the genera *Anguis* and *Cecilia*, in which it resembles what is found in lizards; and in *Amphistæna*, *Eryx*, &c., traces, merely, of either superior or inferior spinous processes can be detected.

The ribs of serpents are enormously numerous, their number varying, according to the proportions of the species, from 51 pairs (*Sheltopusick*), up to three hundred and twenty pairs (*Python*). Each pair of ribs is moveably articulated, by means of two slight concave surfaces, with corresponding articulating facets of the transverse processes of the corresponding vertebra, forming a kind of double ball and socket joint, which allows of an unusual extent of motion. There is no vestige of a sternal apparatus in any of the Ophidian reptiles, but each rib terminates by a single tapering cartilage, which is attached by muscular connexions, to be described hereafter, to the abdominal scuta of the integument.

Myology of Chelonian Reptiles.— In the Chelonian reptiles*, the cervical portion of the spine is composed of long and very moveable vertebræ, which form a curve, the concavity of which is upwards, whilst the dorsal region is converted into a broad immoveable shield by the consolidation of the ribs and vertebræ: there consequently cannot be any muscles of the back, whilst those of the neck, on the contrary, are very distinct; nevertheless, the attachments which they necessarily have beneath the back and the ribs, instead of on the outer side, as is usually the case, renders it exceedingly difficult to compare them with those of other animals. Still some points of relationship may be traced between them and those of birds. Thus, in the horizontal portion of the neck, close to the bones, are the *intertransversales*, separable, as in birds, into two sets of fasciculi, one upon the dorsal, and the other upon the ventral aspect. These are the *intertransversarii colli* and *transversarii colli obliqui* of Bojanus.

There is, moreover, in this horizontal part of the neck, the great transversalis, composed, as in birds, of two fascicles inserted into the transverse process of each vertebra, and derived from the transverse processes of the two preceding vertebræ. The anterior longus colli arises from the first dorsal vertebra; it runs along all the ventral aspect of the curvature of the neck, receiving additional fibres from, and giving off tendons to all.

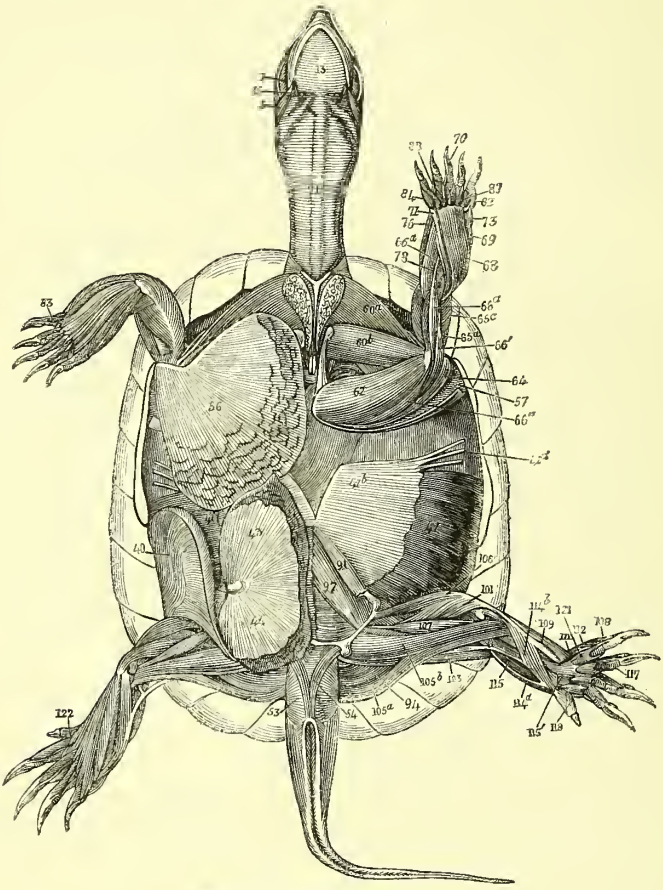
Another muscle, very similar in its distribution to the longus colli posticus of birds, but slightly different in its insertion, arises from the carapax in front of the last vertebra of the neck, and gives off fleshy fasciculi to four or five of the vertebræ that precede it, but it inserts them into the crests, which represent spinous apophyses: moreover, there is no accessory muscle as in birds. In one circumstance, however, there is a resemblance, namely, its last fasciculus, which is very long; those likewise to the head, where it is inserted into the upper aspect of the head, above the splenius: nevertheless it is not digastric, as that of birds. The larger portion of this muscle is named by Bojanus the spinalis colli, and the slip which it gives off to the head the splenius capitis: the tortoise has also a small complexus, which is derived only from the transverse apophyses of two or three of the anterior cervical vertebræ, and runs to the head, external to the splenius and to the fasciculus above mentioned. This splenius, which does not exist in birds, arises in the land and freshwater tortoises from the dorsal crests of the fourth, fifth, and sixth vertebræ, and runs to the head, where, dividing into two portions, it covers the upper surface of the occiput: this is the biventer cervicis of Bojanus. In the turtles its divisions are more widely separated; the internal arises only from the most anterior vertebræ, whilst the external is derived from beneath the anterior edge of the

* Cuvier, Leçons d'Anatomie Comparée, last edition.

carapax; this gives off a fasciculus to the atlas, which is the splenius colli.

So far, even as regards the small muscles of the neck, the analogies are sufficiently satisfactory; but it is not so with the long muscles coming from the dorsal or lumbar portion of the spine, which are replaced by others having a totally contrary

Fig. 191.



Myology of the European Tortoise.

1, temporal muscle; 3, digastricus; 13, mylohyoides; 16, hyomaxillaris; 21, transverse muscle, embracing the neck; 40, obliquus abdominis; 41, transversus abdominis; 43, attrahens, and 44, retrahens, pelvis; 53, sphincter cloacæ; 54, dilator cloacæ; 56, pectoralis major; 57, serratus magnus; 60 *a* and 60 *b*, deltoides; 62, superscapularis, representing the supraspinatus and infraspinatus of other animals; 65 *a* and 65 *c*, triceps brachii; 66 *a*, 66 *b*, biceps brachii; 68, palmaris; 69, flexor sublimis; 70, flexoris profundi tendines ultimi; 71, pronator teres; 73, ulnaris internus; 76, radialis externus longus; 78, supinator longus; 82, extensor proprius digiti minimi; 83, extensores quinque breves digitorum manus; 84, abductor pollicis; 87, lumbricales manus externi; 88, flexores digitorum breves; 91, iliacus internus; 94, glutæi pars; 97, triceps femoris abductor; 101, vastus internus; 103, bicipitis cruris pars; 105 *b*, semimembranosis; 106, sartorius; 107, gracilis; 108, extensoris communis digitorum tendo; 109, tibialis anticus; 111, extensor brevis digitorum; 112, extensor proprius hallucis; 114 *b*, gastrocnemius; 117, extremi tendines flexores, plantarem inter et soleum atque flexorem longum digitorum; 118, flexores breves digitorum pedis; 122, interossii digitorum pedis dorsales. (*After Bojanus.*)

position. Of these, in the land tortoises, and in the fresh-water tortoises, the principal is a thin lamina attached within the carapax to the ribs of the fifth and sixth dorsal vertebræ, and running together with its fellow of the opposite side obliquely forwards, and in the interval between the two lungs, on to the sides of the anterior or horizontal portion of the neck, where it is inserted by fasciculi to the transverse apophyses of the third, fourth, and fifth cervical vertebræ: it terminates by a long fasciculus, which is inserted beneath the head to the basilar bone. This muscle draws the neck and head backwards, and to one side; this is the retrahens capitis of Bojanus.

A little more forward, and beneath the articulation of the fourth and fifth dorsal vertebræ, there is a similar muscle, which might indeed be regarded as a portion of the preceding, and which goes to be inserted into the side of the sixth cervical vertebra: this

draws the head and neck powerfully backwards; it is the retrahens colli of Bojanus. In the opinion of Cuvier, the former of these two muscles corresponds in function to the sacro lumbalis, and to the transversalis; the latter to the longissimus dorsi; but modified in arrangement to suit the disposition of the skeleton. In the turtle they are reduced to a single fasciculus, which runs from the third dorsal vertebra to the basilar bone, performing the office of the rectus capitis anticus.

There is a third still more singular muscle which runs along the spine, receiving fibres from all the vertebræ, and traversing the intervals left between the heads of the ribs and the carapax, and terminating in front upon the anterior surface of the eighth cervical vertebra, which it draws forward, and with it the posterior vertical portion of the neck: its position reminds us slightly of the spinalis dorsi, but its insertion is very different.

A muscular expansion, composed of transverse fibres attached on each side to the sides of the vertebræ, envelopes all the lateral and inferior portion of the neck, including the trachea and the œsophagus, joining in front the mylohyoideus, and connecting itself posteriorly with the inner borders of the plastron: this is a cutaneous muscle, similar to that which envelopes the neck of birds.

In the Chelonian reptiles, the muscles of the head cannot be designated by the same names as those of birds and mammalia, because the carapax gives origin to the greater number of them; we must therefore eontent ourselves by indicating their attachments. Upon the posterior part of the neck we remark, first, at the anterior edge, towards the angle of its crescentic margin, a broad muscle which runs as far as the lateral and posterior parts of the head, where it is inserted: this will draw the head backwards.

2d. Beneath, and from the middle of the anterior crescentic space, there arises another muscle, which is slender and round, and which, separating itself from its fellow of the opposite side, so as to form a figure of V, runs to be inserted upon the external border of the preceding: its office is similar to that of the last.

3d. The analogue of the splenius capitis arises from the spinous processes of the third, fourth, and fifth vertebræ of the neck by distinct slips, and is inserted into the occipital arch: this is the elevator of the head.

4th. The analogue of the rectus anticus major arises from the inferior tubercles of the four cervical vertebræ which succeed the first, and is inserted fleshy into the basilar fossa beneath the condyle.

5th. The trachelomastoideus arises from the inferior tubercles of the second and of the third cervical vertebræ, by two thin aponeurotic tendons; it is inserted thick and fleshy into the eminence which corresponds with the mastoid process: this muscle bends the head to one side.

6th. Lastly, at the upper part of the cervical portion of the spine is a short muscle, which runs from the lower border of the hole formed by the temporal fossæ to the spinous apophyses of the first, second, and third cervical vertebræ.

In front of the neck may be remarked the analogue of the sternomastoideus which arises from the strong aponeuroses which covers the humerus near its articulation with the scapula. Its inferior third only is visible when the skin is raised, the anterior two-thirds being covered by a transverse muscular expansion representing the mylohyoideus, and the platisma myoides. It is inserted underneath the apophysis that corresponds with the mastoid process. Its action will be to draw the head inwards, and slightly to elevate the shoulder.

The rectus capitis anticus arises from the inferior spine of the third vertebra of the back, and is inserted by a thin tendon into the basilar process of the occipital bone.

In the Chelonian reptiles the head is articulated with the atlas by means of a single condyle; in the land-tortoises it is prolonged and divided into two; in the turtles it presents three articulating surfaces resembling the leaf of trefoil. As this tubercle penetrates very deeply into the corresponding cavity of the atlas, the lateral movements of the head must be extremely limited; the other movements of the head in the Chelonians are those of protraction and retraction: these depend upon the flexion and extension of the neck.

In the Trionyx, Nature has doubly provided against any lateral movement in the posterior region of the neck; first, the articulations of the last eervical vertebra with the first dorsal are disposed so as to form an angular hinge, the posterior articular apophyses of the cervical forming a hollow cylinder, whilst the anterior articulating process of the dorsal is likewise cylindrical; secondly, the body of the eighth cervical terminates anteriorly in two condyles, which are received in corresponding cavities in the body of the seventh.

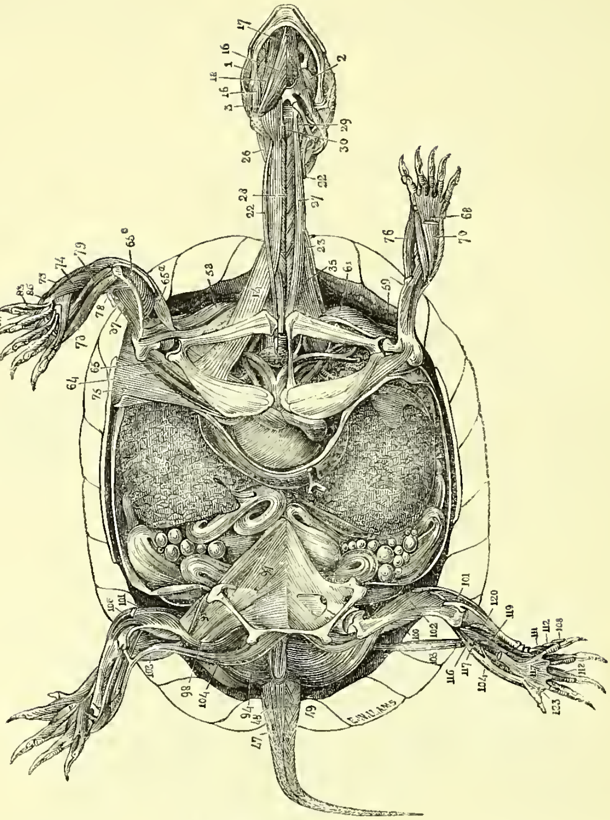
In the *Matamata*, which, instead of bending its neck vertically, bends it by lateral flexion, the disposition of the articulations is entirely different. The body of the eighth cervical vertebra is compressed laterally, and rounded at each end; that of the seventh, on the contrary, is excavated at both extremities; that of the sixth rounded posteriorly, and hollowed in front; the fifth rounded at both ends; and the others, as usual, concave posteriorly and convex before.

It results from this arrangement, combined with the disposition of the articular apophyses, that the neck is capable of a double lateral curvature.

Muscles of the Shoulder.—These muscles in the Chelonian reptiles differ considerably from those of other vertebrate animals: they are four in number.

The first is attached beneath the edge of the carapax between the two ribs, and the pieces usually regarded as sternal ribs, from the second to the fifth. It is very thin, and

Fig. 192.



Myology of the Tortoise.

1, temporalis ; 2, pterygoideus; 3, digastricus maxillæ ; 14, omohyoideus; 16, hyomaxillaris; 17, genioglossus ; 18, hyoglossus ; 22, sternomastoideus ; 26, trachelomastoideus ; 27, retrahens capitis collique; 28, longus colli; 47, extensor caudæ; 48, flexor caudæ lateralis; 49, flexor caudæ inferior; 58, latissimus dorsi; 59, subclavius; 64, subscapularis; 65*a*, 65*c*, triceps brachii; 70, flexor profundis; 73, ulnaris internus; 74, ulnaris externus; 76, radialis externus longus ; 78, supinator longus ; 79, supinator brevis ; 83, extensores quinque breves digitorum manus ; 85, abductor digiti minimi ; 88, flexores breves digitorum quatuor ; 91, iliacus internus ; 94, glutæus ; 97, triceps abductor femoris ; 98, pectineus ; 100, vastus externus ; 101, vastus internus ; 102, crureus ; 103, biceps cruris ; 104, semitendinosus ; 108, extensoris communis digitorum pedis pars ; 111, extensoris brevis digitorum pars ; 112, extensoris proprii hallucis pars ; 116, soleus ; 117, flexor longus digitorum pedis ; 119, tibialis posticus ; 120, interosseus cruris ; 123, interossei digitorum pedis plantares.

runs to the external border of the coracoid bone. From these insertions it cannot but be regarded as the serratus anticus (*costo coracoidien*) (*fig.* 191. 57).

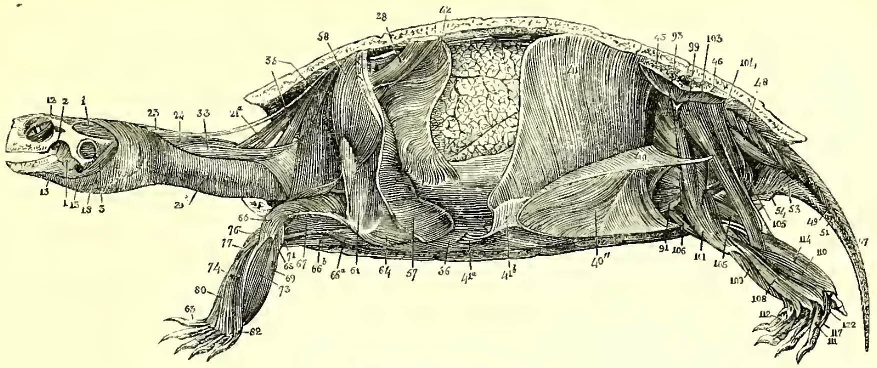
2d. The elevator of the scapula is inserted at the middle internal portion of the scapula, and derives its origin by seven fleshy slips from the transverse apophyses of the seven last vertebræ of the neck.

3d. Another small elongated muscle is attached beneath the carapax, near the sternal extremity of the first rib, and is inserted upon the dorsal extremity of the first bone of the shoulder: this is probably all that remains of the serratus magnus, for it must not be forgotten that here the muscles, as well as the bones, are in an inverse position. The above description is taken from the turtle; in the land-tortoises the second muscle is very strong, and occupies all the length of the border of the scapula. Bojanus considers it as representing the Scalenus.

4th. There is a thin muscle met with in the fresh-water tortoises, of which Bojanus makes no mention ; this is inserted upon the anterior margin of the acromion ; it runs along the side of the neck, but without any attachment to the bones ; it is lost in the general aponeurosis. If this be not regarded as a platysma, it can only represent the trapezius. In the emydes, vestiges of a dorsal cutaneous muscle are inserted into the aponeurosis of the subscapularis.

Muscles of the Arm.—In order to understand the arrangement of the muscles of the shoulder and arm in the Chelonian reptiles, it is necessary to bear in mind that their scapula is styliform, that the acromion and the coracoid are singularly elongated, and that the entire scapula with the humerus are

Fig. 193.

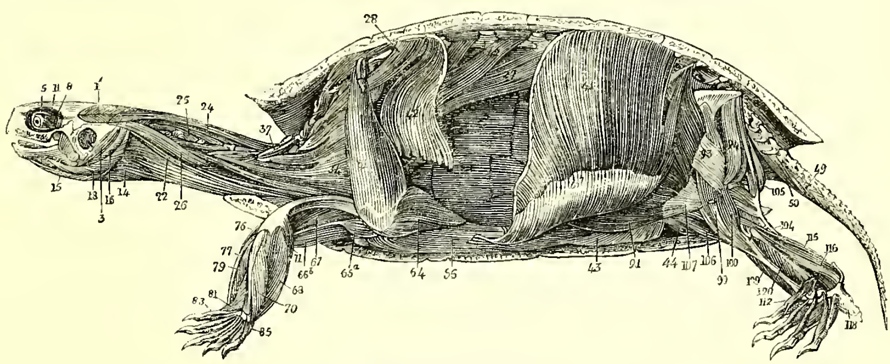


Myology of the Tortoise.

12, palpebralis, representing the orbicularis muscle of the eye; 23, splenius capitis; 24, biventer cervicis; 33, transversalis cervicis; 35, spinalis cervicis; 40, obliquus abdominis; 41, 41*a*, 41*b*, transversus abdominis; 42, a muscle thought by Bojanus to be analogous to the diaphragm; 45, adducens pelvim; 46, abducens pelvim; 47, extensor caudæ; 48, flexor caudæ lateralis; 49—51, flexores caudæ, inferior, lumbalis et obturatorius; 53, sphincter cloacæ; 58, latissimus dorsi; 110, peroneus. *The other muscles are indicated by the same letters as in the preceding figures.*

so disposed that the coracoid bone, instead of being anterior, as in mammalia, is internal, and that the acromion, instead of being external, is anterior; this arrangement, in fact, exists more or less in all oviparous vertebrata.

Fig. 194.



Myology of the Tortoise.

5, rectus oculi superior; 8, rectus oculi externus; 11, suspensor oculi; 14, omohyoideus; 16, hyomaxillaris; 18, hyoglossus; 22, sternomastoideus; 24, biventer cervicis; 25, complexus; 34, scalenus; 37, transversarii colli obliqui. *The other muscles as in preceding figures.*

The analogue of the great pectoral (*fig.* 191, 56) is composed of two superficial portions, one of which is attached to a ridge on the anterior part of the plastron, and goes to be inserted into the small tuberosity of humerus: the other is much more extensive; it arises from a great portion of the internal surface of the plastron, and is likewise inserted by a flattened tendon into the lesser tuberosity of the humerus, but it is continued by an aponeurotic expansion, which spreads like a fan over the inferior surface of the arm, and even of the fore-arm: its tendon is united to that of the preceding.

The analogue of the deltoid (*fig.* 191, 60*a*, and 60*b*) arises from the extremity of the acromion, and goes to be inserted upon the external surface of the small tuberosity of the humerus, uniting its tendon to that of the infra-spinalis.

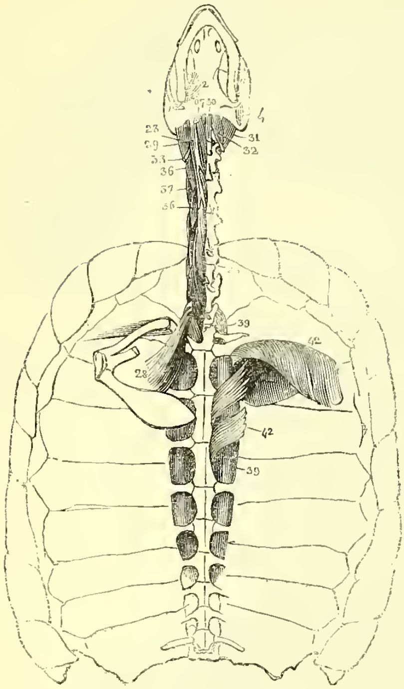
The latissimus dorsi (*fig.* 192. 58) arises from the lateral part of the carapax as far as the articulation of the second rib, and runs nearly vertically towards the humerus, joining its tendon with that of the teres major, to be implanted in a fossa situated at the base of the internal tuberosity.

The supra-spinatus arises from the posterior aspect of the spine of the scapula, and runs to be inserted into the external tuberosity. In the turtles it is reinforced by a large muscle derived from the anterior edge and the superior surface of the extremity of the coracoid.

The infra-spinatus arises from the posterior border of the spine of the scapula, and runs to

oin its tendon to that of the deltoid. In the turtles it is prolonged over all the posterior face of the acromion, and is inserted a little higher up than the deltoid.

Fig. 195.



Myology of the Tortoise.

2, pterygoideus; 4, dilator tubæ; 29, rectus capitis anterior longus; 30, rectus capitis anterior minor; 31, rectus capitis posterior major; 32, rectus capitis posterior minor; 36, intertransversarii colli; 37, transversarii colli obliqui; 39, longissimus dorsi; 42, diaphragmaticus.

The subscapularis (*fig.* 201. 64) is the strongest muscle of the arm; it arises from all the posterior surface of the scapula, and from three-fourths of the superior face of the coracoid, and runs to attach itself broadly to all the anterior face of the internal tuberosity; its coracoid portion describes nearly a quarter of a circle to arrive at its destination. Its action must be powerfully to rotate the arm at the same time that the scapular portion advances it forward.

The teres major arises from the posterior edge of the scapula, and unites its tendon to that of the latissimus dorsi.

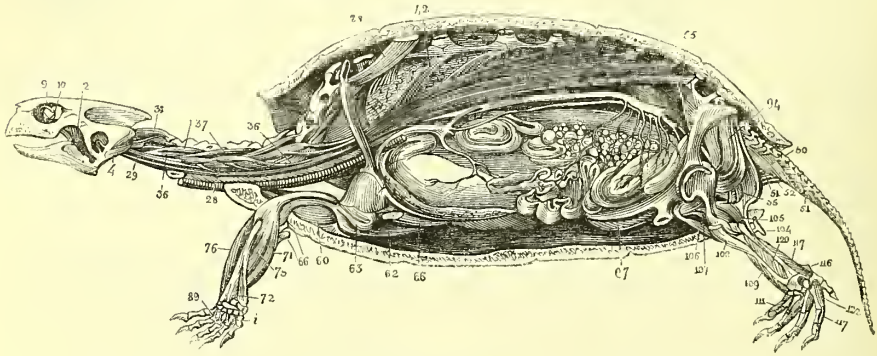
In the turtles there is a teres minor, which arises from the anterior portion of the posterior border of the scapula, and runs to be inserted close to the deltoid.

The coraco-brachialis consists of two portions, as in some mammalia, one of which, the larger, arises broadly from the inferior surface of the coracoid bone; the other, much smaller, arises between the preceding and the biceps: both are inserted near the subscapularis into the internal tuberosity of the humerus.

It will be seen from the above account that the muscles of the arm in the Chelonian reptiles are very similar to those of mammalia, only their different portions are more widely separated on account of the great prolongation of the acromion, and of the coracoid.

Muscles of the Fore-arm. — The bones of the arm and the fore-arm not having undergone the same distortion as those of the shoulder, the muscles are less changed from the usual arrangement. The biceps alone coming from the coracoid bone, must necessarily follow its

Fig. 196.



Myology of the Tortoise.

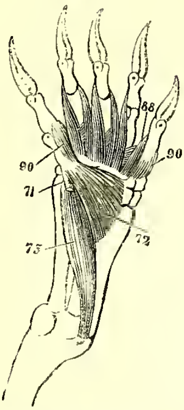
9, obliquus oculi superior; 10, obliquus oculi inferior; 27, retrahens capitis collique; 52, flexor caudæ ischiadicus. *Other muscles indicated by same letters as in preceding figures.*

movements; it, however, always arises from its anterior margin, and passes along the bicipital groove when that exists in the Chelonians. It is only fleshy at its coracoidal extremity; all the rest consists of a tendon, which runs along the humerus to be inserted into the radius.

The brachialis internus occupies its usual situation, as also does the triceps brachii; the latter, however, is proportionally small, and

in the turtles appears to have no scapular origin.

Fig. 197.



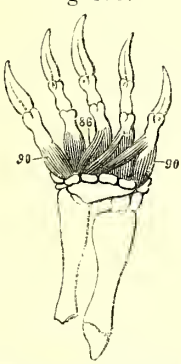
Myology of the Tortoise

71, pronator teres (insertion of); 72, pronator quadratus; 75, radialis internus; 88, flexores digitorum breves; 90, interossei digitorum manus interni.

There is only one supinator*, which is inserted into the wrist; it arises from the external condyle, but in the turtles this muscle is wanting. Both the pronators of the forearm are present in the land-tortoise; however, the pronator quadratus is very small, and situated close to the carpus.

Muscles of the Hand. — The muscles of the

Fig. 198.



Myology of the Tortoise.

86, abductor digiti tertii, quarti et quinti; 90, interossei digitorum manus interni.

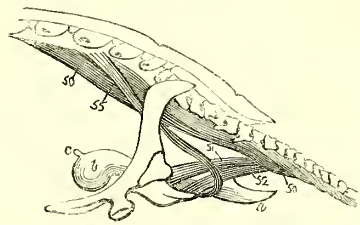
fingers are, in the turtle, few in number, their hand being so flattened out into the shape of a fin or oar as to require neither flexors nor extensors of the fingers; in these, therefore, the analogue of the extensor digitorum communis is confounded with the general aponeurosis. The flexor communis is slightly more distinct; and the interossei, the abductors and adductors of the thumb and of the fifth finger exist, the latter serving to expand or to contract the oar.

* Bojanus regards the muscle marked 79 (*fig*. 192) as a supinator brevis.

In spite of the extreme shortness of the hand in the land-tortoises, the muscles are well developed, and the extensor communis, the extensor, and the long abductor of the thumb, the flexor sublimis, the flexor profundus, the adductor of the thumb, and the abductors of the little finger, as well as the interossei, are met with.

Muscles of the Pelvis. — In the tortoise the

Fig. 199.



Myology of the Tortoise.

a, glans penis; *b*, bulbus penis; *c*, vein derived from ditto; 50, flexor caudæ lumbalis; 51, flexor caudæ obturatorius; 52, flexor caudæ ischiadicus; 55, protrahens penis.

muscle analogous to the quadratus lumborum spreads out beneath the carapax between the antepenultimate ribs: it is inserted into the ileum near the articulation of that bone with the sacrum, that articulation being in the Chelonians moveable.

This mobility of the pelvis is aided by the analogue of the rectus abdominis, which, instead of spreading out beneath the belly, is attached under the posterior extremity of the plastron by two fleshy bellies, one in front and the other behind; both run to be inserted into the anterior margin of the external ramus of the pubis.

Muscles of the Thigh. — In the land and fresh-water tortoises, although the ossa ilii are very narrow, the muscles belonging to the thigh are of considerable thickness. The glutæus maximus, which might almost be mistaken for a pyramidalis, is only attached to the ileum by a small proportion of its fibres, the remainder are derived from the transverse apophyses of the caudal vertebræ. The glutæus medius and minimus, united together at their origin, constitute a mass which arises from all the external surface of the ileum, from its anterior border, slightly from its internal surface, and even from the inferior surface of the seventh rib: this muscle divides into two tendons, one of which, that of the glutæus medius, is inserted into the trochanter; the other, that of the glutæus minimus, a little lower down into the body o. the femur.

The obturator internus is a very strong muscle arising from the upper aspect of the internal ramus of the pubis, and winding around the ischium, as in mammalia, to be inserted into the great trochanter.

The quadratus femoris exists, but neither gemelli nor pyramidalis are present.

There is no psoas; but the iliacus is strong, and arises from the upper part of the internal

surface of the pubis, confounding its anterior margin with that of the glutæus medius. The obturator externus (adductor of Bojanus) arises by two portions, one coming from the pubis, the other from the ischium; their two tendons unite to form a broad tendon, which is inserted into the two trochanters.

The adductors of the thigh do not arise from the pubis, but from the ischiadic portion of the symphysis.

A muscle, the analogy of which it is difficult to recognise, arises from the upper surface of the pubis, and goes to be inserted by a strong tendon at the side of the iliacus (iliacus internus of Bojanus, surpubien of Cuvier). In the turtles there is no iliacus, and the suprapubic muscle divides into two fasciculi, the external of which goes to the knee, and joins the rectus of the thigh.

Muscles of the Leg. — The muscles of the leg are more recognisable than those of the thigh.

In the land-tortoises these muscles are the triceps; the sartorius, which is divided into two portions; the semimembranosus, which has a large accessory slip derived from the coccyx; the rectus anticus, which is situated slightly internally, has an origin from the external ramus of the pubis, and is connected with the articular capsule of the knee joint; the gracilis is confounded at its origin from the ischium with the adductors of the thigh, but it separates from them, and is inserted at some distance from the head of the tibia. In the turtles the muscles are not so thick as in the land-tortoises; the advanced position of the pubis gives to the anterior rectus great force in extending the thigh and the leg, for it is inserted into the knee almost at a right angle. The biceps and the semimembranosus arise from the coccygeal region only.

In the terrestrial tortoises the movements of the foot upon the leg, and of the different parts of the foot one upon the other, are very limited, and consequently the muscles which execute them are indistinct.

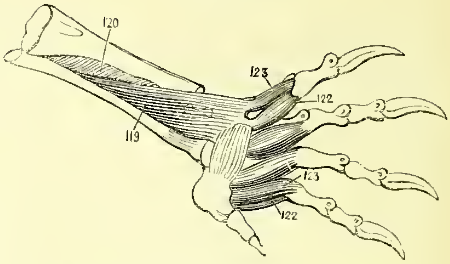
There is but one peroneus, which is confounded by one of its margins with the extensor communis, and which is inserted into the os calcis and into the cuboid.

The gastrocnemius externus alone takes its origin from the femur; the gastrocnemius internus arises from the tibia and joins itself to the solæus. This latter is divided into three portions, one external, one median, the other internal. These muscles, in conjunction with the peronei and the long flexor of the toes, form beneath the foot a thick tendinous mass; they extend the foot upon the leg, and flex the latter upon the thigh; but it is next to impossible to distinguish the different portions.

The tibialis anticus is distinct.

In the turtles which have the foot, like the hand, flattened into the shape of an oar, the gastrocnemii are disposed as in the land-tortoises, and the soleus is equally strong. There exists, moreover, a slender plantaris longus, which arises from the external tuberosity of the femur by a long round tendon, and which terminates in a broad expansion,

Fig. 200.



Myology of the Tortoise. (*After Bojanus.*)

119, tibialis posticus; 120, interosseus cruris; 122, interossei digitorum pedis dorsales; 123, interossei digitorum pedis plantares.

which is inserted partly into the os calcis, and partly into the plantar fascia. This muscle is from its position an adductor of the foot. The tibialis anticus preserves its ordinary relations; but the tibialis posticus runs from without to within, and its tendon becomes lost in the plantar fascia.

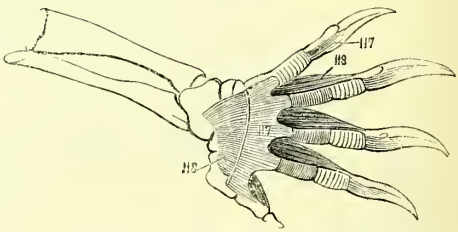
The toes of the Chelonians not having more flexibility than their fingers, the muscles of the foot are much confused. The extensor communis longus digitorum, as in all other reptiles, only reaches as far as the bones of the metatarsus. The extensor brevis alone reaches to the phalanges of the toes.

There is, however, a proper extensor for the great toe, which arises from the inferior extremity of the fibula, an abductor of the little toe, and interossei, which latter, as in mammalia, are both adductors and abductors.

In the turtles the extensor communis spreads out as it approaches the toes, and forms a broad aponeurosis, which covers the whole foot.

The extensor longus, and the abductor of

Fig. 201.



Myology of the Tortoise. (*After Bojanus.*)

117, tendons of the flexor longus digitorum; 118, flexor brevis digitorum pedis.

the inner toe, arise from the inferior extremity of the fibula, and are inserted into the metatarsal bone that supports this toe, as well as into the first and second phalanges.

Another muscle, which also arises from the inferior extremity of the fibula, is inserted into the whole length of the metatarsal bone of the fifth toe, and upon its first phalanx: it is both an extensor and an adductor.

The flexor brevis digitorum gives off a slip to each of the three middle toes.

Myology of Ophidian Reptiles. Muscles of the Spine.— In serpents, as might be expected, the muscles of the spine are very completely developed, and easy to identify.

The spinalis dorsi arises from the lateral surface of the spinous processes of the vertebræ, and likewise receives tendons of reinforcement from the longissimus dorsi, which spread out and are lost upon its inferior surface ; this muscle divides itself internally into as many fasciculi as there are vertebræ, each fasciculus terminating in a very long tendon, which runs in an aponeurotic sheath to be inserted into the spinous process of the vertebra to which it is destined.

The longissimus dorsi arises by fleshy fibres from the extremities of the articular apophyses, which here perform the office of transverse processes. These slips, after having become united with each other, give off two sets of tendons, one of which runs obliquely to assist in giving origin to the spinalis dorsi; the others descend in like manner, and constitute the only tendons of origin of the sacro-lumbalis, so that this muscle cannot be said to have any direct insertion upon the vertebral column.

The sacro-lumbalis arises from the tendons of the longissimus dorsi just described, and divides itself externally into slips, each of which is inserted by a slender tendon into the posterior edge of the upper third of one of the ribs.

Under the spinalis dorsi is found the semi-spinalis (transverso-spinalis), and beneath this the interspinalis.

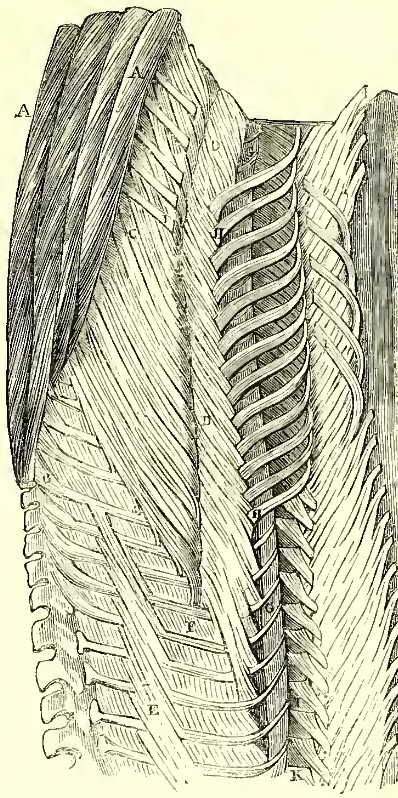
On the inferior aspect of the vertebral column there is found a muscle in all respects analogous to the longus colli, except as regards its extent, and which might be called the transverso-spinalis inferior: this extends from the inferior spinous process of one vertebra to the transverse processes of the second and third succeeding vertebræ.

All the above six muscles exist from the end of the tail as far as the head: their last fasciculi, viz. those inserted into the skull, although their arrangement is slightly altered, cannot be considered on that account as being distinct muscles. The sacro-lumbalis, moreover, on arriving at the caudal region, is inserted into the transverse processes of the caudal vertebræ, instead of into the ribs, so that as the tail becomes attenuated these muscles are blended together: nevertheless, there are always vestiges of them perceptible.

Muscles of the Ribs.— These are the transverso-costal muscles, arising from the transverse processes of each vertebra, and running to be inserted into the following rib, for about the superior fourth of its length.

The great lateral costal muscles which cover the side of the trunk of the body, arise behind the insertions of the preceding, each passing obliquely over four ribs, to which it gives off a few fibres, is inserted into the fifth behind that from which it takes its origin.

Fig. 202.



Lateral View of the Muscles which move the Ribs of the Boa Constrictor.

AA, the straight muscles of the back; B, the first set of muscles, which arises from the transverse processes of each vertebra, and is inserted into the rib behind it, close to its head; C, the second set; DD, the third set; E, the fourth set; F, the fifth set; GG, short muscles which pass from cartilage to cartilage; HH, a set of oblique muscles, which pass from the anterior side of the bony extremity of each rib to the posterior edge of each scutum; II, muscles which pass from the ribs, near their heads, obliquely backwards, to be inserted into the skin at the edge of each scutum; K, muscles of the scuta. (*After Home.*)

The great inferior costals take their origin below the preceding, and are inserted in the same manner, only their direction is more longitudinal, so that they occupy a smaller proportion of the length of the ribs.

The smaller costal muscles are placed between the two preceding sets, and pass from one rib to the next behind it.

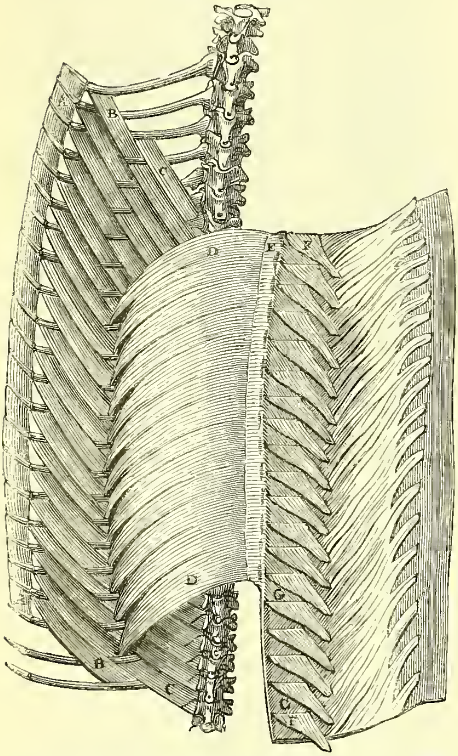
The intercostal muscles occupy their ordinary position, and, as usual, are arranged in two planes which decussate each other.

In addition to the above, there exists in the interior of the thorax an inferior transverso-costal muscle; this arises from the angle of the tubercle to which the rib is attached, and running obliquely forwards, passing three ribs, is inserted into the fourth a little below the

middle of its length. This muscle is described by Sir Everard Home* as being in the boa constrictor divided into two, an upper and a lower portion; but in other species, although a slight line of demarcation may be detected, such a division is scarcely admissible.

From the ribs of serpents muscular fasci-

Fig. 203.



An internal View of the Muscles which move the Ribs in the Boa Constrictor.

A A, the muscles which pass from cartilage to cartilage of the different ribs; B B, a set of muscles which pass from the point of each rib, over two ribs to the middle of the third; C, a similar set of muscles continued from the opposite side of the rib, passing over three ribs to the body of the vertebra; D D, the abdominal muscles which arise from the anterior edge of each rib, and pass to the linea alba; E, the linea alba; F F, the terminations of the oblique muscles which pass from the bony extremities of the ribs to the edges of the scuta; G G, the muscles of the scuta, consisting of two sets, which decussate each other.

culi are given off, which go to be inserted into the skin: some of these arise from the same point as the great lateral costals. Their course is from before backwards, and from above downwards as they run, spreading out like a fan, to be attached to the sides of the ventral scuta. The others arise from the lower part of the rib, opposite the point of attachment of the long inferior costal muscle; these run from behind forwards to be fixed to the angle of a ventral scutum, about three ribs off. The ribs, moreover, give attachment to a visceral muscle.

In serpents there is only one muscle proper to the head, which seems to represent the complexus; this arises from the articular apophyses of the five or six anterior vertebræ, and is inserted into the mastoid bone.

The transverso-spinalis is continued as far forwards as the occipital bone, and thus replaces the recti capitis. The movements of the head upon the spine are, indeed, very limited in the ophidia. The body of the atlas presents three articular facets arranged after the manner of the leaves of a trefoil, which are attached to the occiput beneath the foramen magnum, so that the head is not more moveable upon the atlas than the other vertebræ upon each other.

The muscles of the head of serpents have been carefully dissected by M. Dugès*, M. Duvernoy†, Brandt and Ratzburg‡, and others. The following brief account of this part of their myology, taken from the last edition of Cuvier's Anatomie Comparée, must, however, suffice for our present purpose.

The true serpents have the zygomatic (*tympanic*) bones (*fig.* 205, 7) moveable, and suspended from another bone analogous to the mastoid (6), which is attached to the cranium by means of muscles and ligaments that allow of considerable mobility: the two sides of the lower jaw, moreover, are but loosely connected with each other, and the superior maxillary bones (2) are only united to the inter-maxillary bones (1) by ligaments, so that they can be separated to a greater or less extent; a circumstance which confers upon these reptiles the faculty of dilating their *rictus*, thus enabling them to swallow animals whole which could not otherwise by possibility pass into their mouths. In addition to the above arrangement, the maxillaries (2), the palatine bones, and the ossa pterygoidea (3, 4), are more or less moveable beneath the cranium, so that the animal can raise or depress the palatine or pterygoid arches, as well as those formed by the upper maxilla, and also can separate them, or approximate them to each other.

The muscles subservient to the movements of the jaws are the following: —

All serpents whose mandibular arches are moveable, as above described, have generally three distinct temporal muscles, one anterior, one median, and the other posterior.

The *anterior temporal* (*fig.* 204, *e*) is attached superiorly behind the orbit, and descending downwards and backwards, winds round the commissure of the lips, and turning forward again (*e'*), is inserted into the lower jaw, very considerably in front of the angle of the mouth.

The *middle temporal* (*fig.* 204, *i.*) is partly covered by the anterior temporal, it descends nearly vertically from the middle and upper

* Lectures on Comp. Anat., vol. i.

* Ann. des Sc. Nat. tom. xii. 1827. p. 378.

† Ann. des Sc. Nat. tom. xxvi. 1832. p. 113.

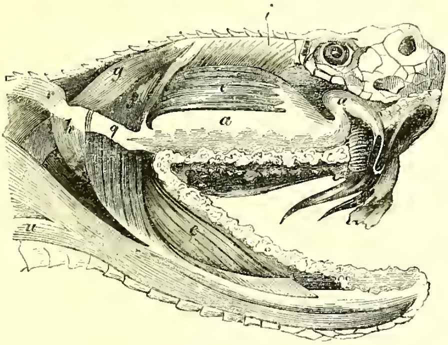
‡ Medezinische Zoologie, 4to. 1829

portion of the temporal fossa, until it meets the jaw into which it is inserted, either separately or conjointly with the anterior temporal.

The *posterior temporal* (*f*), which is always distinct from the two others, descends from the very posterior part of the temporal fossa, along the zygomatic bone (*tympanic*) (*fig.* 205, 7), to the lower, into which it is inserted behind the two others.

The mouth is opened by means of a muscle

Fig. 204.



The Muscles of the Head of the Rattlesnake.

a a, poison gland and its excretory duct; *e*, anterior temporal muscle; *f*, posterior temporal muscle; *g*, digastricus; *h*, external pterygoid muscle; *i*, middle temporal muscle; *q*, articulo-maxillary ligament which joins the aponeurotic capsule of the poison gland; *r*, the cervical angular muscle; *t*, vertebro-mandibular muscle; *u*, costo-mandibular muscle. (*After Duvernoy.*)

analogous to the *digastric* (*g*), which arises from the whole length of the posterior aspect of the zygomatic (*tympanic*) bone, and terminates on each side at the angle of the jaw beyond its articulation.

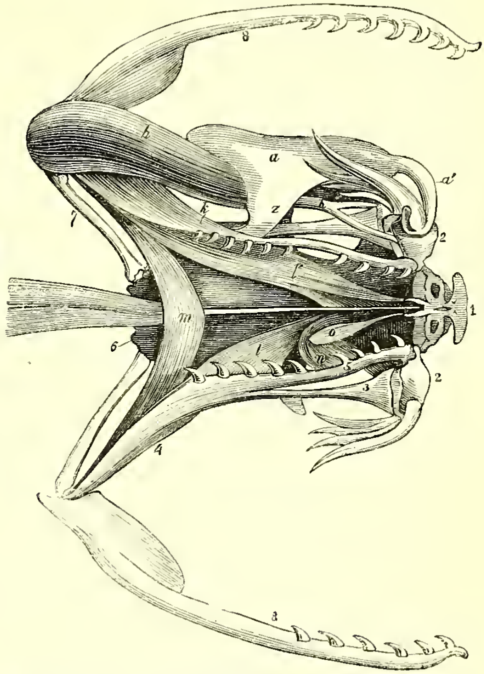
There is likewise a cutaneous muscle which powerfully contributes to depress the lower jaw, something like the *platysma myoides;* this has been named the *costo-mandibularis* (*u*). This, moreover, is assisted by a strong fasciculus (*t*), derived from the spinous processes of the vertebræ immediately behind the cranium, which has been distinguished by the name of the vertebro-mandibularis.

Two sets of muscles are appropriated to the movement of the zygomatic (*tympanic*) bone which supports the lower jaw: of these one arises on each side from the back of the occipital region, and is inserted into the lower portion of the bone above referred to.

The other (*fig.* 205, *m*) is *azygos*, and has been named by M. Dugès *sub-occipito articularis*, its fibres run across beneath the base of the skull, from the articulation of the lower jaw on the one side, to that on the other. The former pair of muscles will draw the branches of the lower jaw upwards and inwards, the azygos muscle will move them inwards and downwards.

The anterior extremities of the lower jaw can be approximated by a little muscle (*fig.* 206, *v*), which passes transversely from one to the other. This muscle, which is tendinous

Fig. 205.



Muscles of the Pterygo-Palatine Apparatus of the Rattlesnake (*Crotalus durissus*). (*After Duvernoy.*)

1, intermaxillary and nasal bones; 2, 2, superior maxillary bones; 3, external pterygoid bone; 4, internal pterygoid bone; 5, palatine arch; 6, mastoid bone; 7, the tympanic bone; *a*, capsule of the poison-gland; *a'*, duct of ditto; *h*, *h*, external pterygoid muscle; *k*, internal pterygoid muscle; *l*, *l*, spheno-pterygoid muscle; *m*, the suboccipito-articular muscle (of Dugès); *n*, the spheno-palatine muscle; *o*, the spheno-vomerine muscle.

along the mesian line, is analogous to the *mylo-hyoideus*; it likewise gives off a slip *v'*, which is attached to the skin.

The muscles belonging to the maxillary and palatine bones are,—

The *external pterygoid* (*fig.* 204, *h*), which, arising from each jaw, runs directly forward as far as the maxillary extremity of the external pterygoid bone, which it draws powerfully backwards. In venomous serpents with anterior poison fangs, which have the external pterygoids very long, and the maxillary bones very short, this muscle is very strong, arising by aponeurotic fibres, from the capsule which encloses the articulation of the lower jaw, whence it runs forwards towards the pouch in which the venomous teeth are lodged, upon which it is partially spread out; its principal attachment, however, is to the posterior apophysis of the superior-maxillary bone, into which it is inserted by a distinct tendon. The use of this muscle is evidently to carry backwards the venomous fangs when they are to be laid flat, and to incline them towards the palate, a position that they retain while in a state

of repose, in which condition it covers them by drawing the inclosing pouch over them.

The *internal pterygoid* (k), shorter and smaller than the external, runs from the alar bone to the posterior part of the lower jaw, which it consequently draws forwards.

The *spheno-pterygoid* (l), which has no analogue in other vertebrata, arises from the mesial portion of the base of the cranium, and runs outwards and backwards to be attached to the inner surface of the pterygoid plate, which it can thus drag forwards and inwards so as to cause the protraction of the superior maxillary bone, thus raising the venom fangs; it will likewise narrow the mouth by causing the approximation of the two internal arches. It is assisted in its action by a muscle, which Cuvier regards as a dismemberment of the temporal, the *post-orbito-palatine*, which runs from the temporal fossa behind the orbit to the palatine arch.

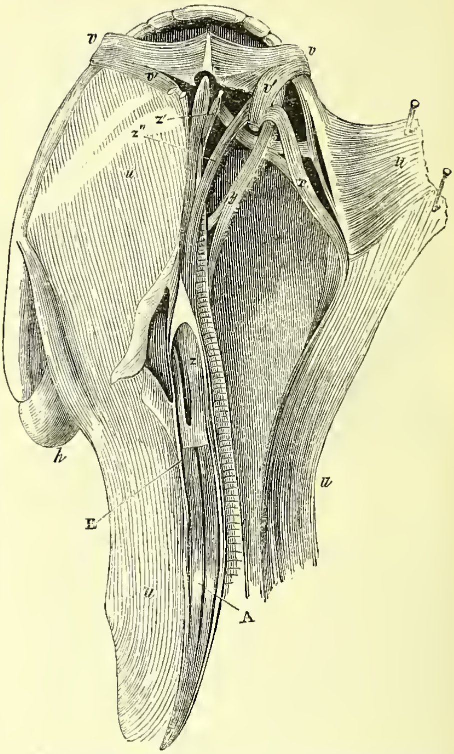
The *spheno-palatine* (*fig.* 205, n) antagonises the two last; it extends from all the length of the palatine arch to the mesial line of the base of the cranium; its direction crossing that of the preceding muscle, above which it is placed. By its contraction it brings backwards the entire upper jaw, approximating at the same time the branches that form it.

Two small muscles (*fig.* 205, o) advance from beneath the sphenoid, and run close to each other to be inserted by a slender tendon into the vomer. These are the *spheno-vomerine* muscles of Dugès, for which it would be difficult to find analogues. These muscles depress the muzzle.

In all the true serpents the tongue is enclosed in a membranous sheath, to be described hereafter; and the os hyoides, which in the ophidia has no connexion with the larynx, consists of two simple cartilaginous stems (*fig.* 206, B,) running parallel to each other, which bend forwards underneath the sheath of the tongue, where they unite to form a sort of arch of almost membranous consistency. Corresponding with this simple form of the os hyoides; the hyoid system of muscles is very simple. The *mylo-hyoideus*, above described as being an adductor of the two divisions of the lower jaw, has some of its fibres confounded with those of the costo-mandibular muscles (*figs.* 204. 206, u), which, coming from the anterior ribs, is attached to the lower margin of the inferior maxilla. Its central fasciculi are adherent to the rami of the os hyoides, and more especially to the membranous arch which they form in front. They can therefore draw it either forwards or backwards, accordingly as it is the maxillary or the costal portion which contracts; and thus these fasciculi hold the place of both sterno-hyoidei and genio-hyoidei. In serpents, therefore, there are no muscles exclusively appropriated to the os hyoides.

The tongue of serpents is slender, cylindrical, and forked at its extremity. It is lodged in a membranous sheath, the opening of which is situated near the anterior part of the mouth, and the animal can protrude it from its mouth to nearly its whole length, using it as an instrument of touch, apparently comparable in

Fig. 206.



Muscles of the Throat of the Rattlesnake (*Crotalus durissus*).

A, retractor muscles of the tongue (Hyo-vaginiens); B, cornua of the os-Hyoides; h, external pterygoid; u, u, u, u, costo-mandibular muscles; v, v, anterior adductor muscle of the rami of the lower jaw; v', v', portion of the preceding connected with the skin of the throat; x, posterior adductor of the rami of the lower jaw; y, a muscle running from the symphysis of the lower jaw to the sides of the trachea (genio-trachien); z, geno-vaginalis, representing the genio-glossi; z', z'', external and internal origins of ditto.

some respects to the antennæ of insects. The muscles by the agency of which it is protruded, are the *genio-vaginales* (*fig.* 206, z), representing the genio-glossi. These arise by two fasciculi, of which the internal and smallest (z') arises from the tendinous median portion of the adductor of the inferior maxillæ (v); whilst the external (z''), which is the strongest, takes its origin from the extremity of the lower jaw itself: these two portions unite and form a narrow band, which becomes applied to the sides of the sheath of the tongue, along which it is continued backwards to its extremity.

The retractors of the tongue (*fig.* 206, A) are analogous to the hyo-glossi; they arise around the extremities of the rami of the os hyoides, and running forwards conjointly, enter the sheath of the tongue, and its proper investing membrane; so that they constitute the entire

substance of that organ. The flexibility of the tongue seems to depend entirely upon the different muscular fasciculi of which these muscles are composed, having the power of contracting separately, some being longer or shorter than others, accordingly as they terminate successively in the proper membrane of the tongue to which they are attached; for there seem to be no transverse or oblique fibres constituting intrinsic lingual muscles.

The mechanism by which the Cobra de Capello, when irritated and ready to seize its prey, expands the skin of the neck, giving it the appearance from which the snake takes its name, consists entirely of muscles, acting upon the ribs and external skin of the animal.

From the rounded form of the hood, the skin has the appearance of being inflated; but the most careful examination does not discover any communication between the trachea or the lungs, and the cellular membrane under the skin.

In this snake, the ribs nearest the head, to the number of twenty on each side, have a different shape from the rest; instead of bending equally with the other ribs towards the belly, they go out in a lateral direction, having only a slight curvature, and when depressed, lie upon the side of the spine, on one another.

In the extended state of the ribs, the skin of the back is brought over them, forming the hood; and in their depressed state the hood disappears.

The ribs are raised by four sets of muscles: one set from the spine to the upper edge of each rib; a second set from the ribs above, passing over two ribs to the third rib below; another set have their origins from the rib above, pass over one rib, and are inserted into the second below; and a fourth set pass from rib to rib. The combined effect of these four sets of muscles raises and extends the ribs.

The skin of the back is brought forwards on the neck, by a set of very large muscles, going off from each of the first twenty ribs on each side, a quarter of an inch from their head, by a tendinous origin, which soon becomes fleshy; the longest of these muscles are two inches long. They are inserted into the skin, and, when the ribs have been first extended, have the power of bringing the skin forwards to a great extent.

Myology of Salamander (*Salamandra terrestris*). In-order to complete our survey of the myology of the reptilia, it has been deemed advisable to introduce in this place a brief sketch of the muscular system of the amphibia, which is obviously arranged upon the same plan as that of the quadruped reptiles properly so called, and from its comparatively embryo condition is a subject of much interest.*

Muscles of the Head. — The movements of the eye are effected in the usual manner by means of the four recti and two oblique muscles, the disposition of which is similar to what exists in reptilia generally.

The movements of the jaw subservient to mastication, are performed by the agency of five muscles. Of these the first is a long muscular slip (*fig.* 207, 1.) that takes its origin from the arch and spine of the first vertebra of the neck, and which, together with a broad triangular muscle (2), corresponding to the temporalis, that arises from the lateral region of the os-frontis and the parietal bones, is inserted in front of the os quadratum into the upper margin of the lower jaw. A third muscle (3), analogous to the masseter, arises at the upper extremity of the os quadratum towards its anterior part, and extends to the external surface. The three preceding muscles serve to close the jaws; they are antagonised by a short muscle (4) derived from the quadrate and temporal bones; whose attachment to the lower jaw is placed behind the centre of motion of the articulation of the jaw, and consequently its effect will be to open the lower jaw.

Lastly, there is an external pterygoid muscle, provided for the lateral movements of the inferior maxilla.

Muscles of the Trunk. — Running along the whole length of the back there is the broad lateral muscle (*fig.* 207, 5), which likewise forms the principal part of the lateral walls of the abdomen. This muscle forcibly reminds us of the great lateral masses of muscle which form the principal part of the body of fishes, and, in like manner, it is divided by tendinous intersections into as many portions as there are vertebræ in the spine. Its commencement may be traced as far forwards as the occipital quadrate and temporal bones: it likewise has points of origin from the spinous and transverse processes of the whole vertebral column. These two lateral masses are separated above by a deep furrow (5 *a*), which is filled up with a series of cutaneous glands peculiar to these animals. The dorsal portion is with difficulty separated into an upper and lower stratum, of which the upper and more external may be compared to the sacro-lumbalis, while the lower and broader one seems to represent the longissimus dorsi. The cephalic extremity, having numerous points of attachment in the neck, and likewise the occipital region of the skull, forms several muscular bundles, more or less distinct from each other, which represent the muscles of the neck.

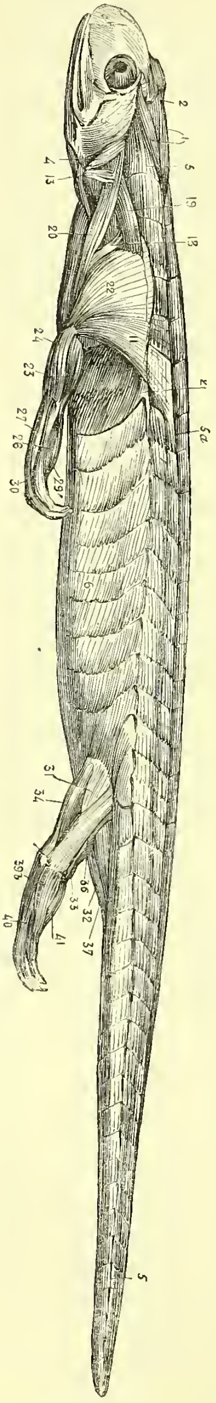
The representative of the external oblique muscle of the abdomen (6), is here evidently merely a continuation of the great lateral muscle above described. In this region, however, it attaches itself more particularly to the rudiments of the ribs and to the contiguous transverse process of the vertebra, extending from the second vertebra of the neck as far back as the pelvis; inferiorly, it is connected with its fellow of the opposite side by a tendinous interlacement, representing the linea alba.

The internal oblique muscle of the abdomen is represented by the inner layer of the preceding. By the partial separation of these two muscular layers, a sheath is formed which partially encloses the *Pubo-hyoideus*.

* See the article AMPHIBIA.

The last named muscle (*Shamzungenbein-muskel*) (*fig.* 208, 7) arises partly from the os-

Fig. 207.



Muscles of Salamander terrestris.

pubis and partly from the outer border of the Y-shaped pelvic cartilage, whence it runs forward along the whole length of the abdomen, enclosed in a sheath, formed between the internal and external oblique muscles of the abdomen as far as the throat, where it is inserted into the middle cornea of the os-hyoides.

The rectus abdominis (*fig.* 208, 8) takes its origin entirely from the Y-shaped pelvic cartilage, and, first attaching itself to the triangular lower rudiment of the sternum, over which it passes, it becomes again connected with the upper transverse piece of the sternum, from whence it sends a slip forwards to be inserted into the centre of the lower jaw: this last portion represents the genio-hyoideus.

In its course, this muscle is divided by several tendinous intersections. It is, moreover, attached with some firmness to the pericardium, in the neighbourhood of which it gives off two additional slips of muscle, one of which passes obliquely outwards to join the pubo-hyoid; the other (10) runs to be inserted into the scapula, becoming likewise connected with the scapulo-humeral articulation.

The mylo-hyoideus (*fig.* 208, 11) fills up the entire space betwen the arches of the lower jaw, from the angle of which, likewise, arise two cutaneous muscles (*fig.* 207, 12) and (*fig.* 208, 13), one of which extends into the skin of the inferior and anterior region of the neck, whilst the other mounts backwards and outwards to be similarly inserted into the skin upon the sides of the cervical region. A muscle (*fig.* 208, 14) passes from the lower jaw near its symphasis, to be inserted into the extremity of the anterior cornu of the os-hyoides; whilst a second slip (15) passes from the anterior to the central cornu of the latter bone.

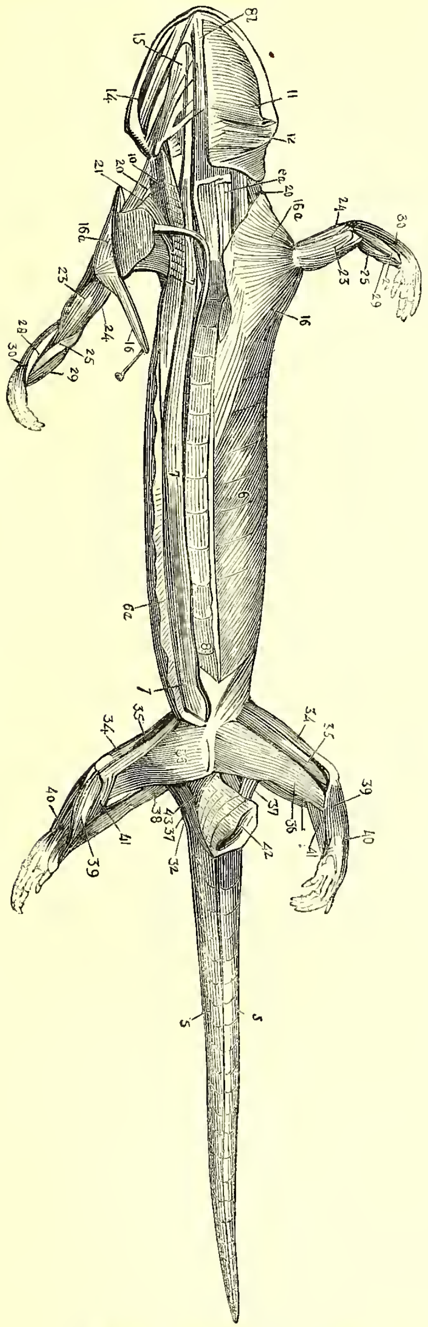
Muscles of the Extremities. — The pectoralis major (*fig.* 208, 16) consists of two portions, one of which, 16 *a*, represents the clavicular portion in the human subject; it entirely covers the lower surface of the shovel-shaped clavicle, so that it seems to form a distinct muscle.

The following muscles are immediately recognisable from their position: The latissimus-dorsi (*fig.* 207, 11); the levatores-scapulæ (*fig.* 207, 18 and 19); a muscle (20), the office of which is to draw the shoulder forwards. This muscle is derived from the sides of the occiput and anterior cervical vertebra, and extends to be inserted into the shoulder-blade near its articulation. The serratus magnus anticus (*fig.* 208, 21) consists of only two small slips derived from the transverse processes of the second and third vertebræ of the neck, and connected with the great lateral muscle of the trunk. The shoulder likewise possesses a muscle (22) that represents both the supra and infra spinatus, and a subscapularis occupying its usual position.

The muscles of the humeral region are the representative of the biceps, and brachialis

internus (*fig.* 208, 23), and the triceps extensor of the fore-arm.

Fig. 208.



Muscles of Salamander terrestris.

On the fore-arm may be distinguished the flexor carpi radialis (25), the flexor carpi ulnaris (*fig.* 207, 26), the extensor carpi ulnaris (27), the extensor carpi radialis (*fig.* 208, 28), a flexor communis digitorum (29), and an extensor communis digitorum (30).

Muscles of the hinder Extremity. — The thick flexor of the thigh (*fig.* 207, 31), representing the iliacus internus, arises broadly from the whole inner surface of the os ilei passes over the os pubis, and is inserted into the femur below its middle. The long extensor and adductor of the thigh (32) arises from the third and fourth caudal vertebræ, and is inserted into the posterior aspect of the femur about its middle.

The long abductor of the leg (*fig.* 207, 33) arises from the external surface of the os ilei, and is inserted into the tibia about its lower third. The anterior abductor of the thigh (*figs.* 207 and 208, 34) arises from the anterior and internal surface of the os ilei, and is inserted into a broad tendinous expansion that covers the knee-joint. The thin flexor of the leg (*fig.* 208, 36) arises from the inferior lateral surface of the os ilei, and is inserted into the outer part of the head of the tibia.

A long muscular slip (*figs.* 207 and 208, 37) arises from the transverse processes of the third and fourth vertebræ of the tail, and is inserted into the back of the thigh bone.

The chief muscle of the sole of the foot (38) arises from the side of the sacrum, and is inserted into the thick fascia of the sole. The other muscles of the foot are an extensor and abductor of the tarsus (39), which arises from the upper end of the tibia, and is inserted into the outer surface of the tarsal bone. An extensor longus digitorum pedis (40) arising from the fascia of the knee, and the anterior surface of the ligaments of that joint. This furnishes a tendon to each of the five toes. The flexor longus digitorum (41), arising from the upper extremity of the tibia, and dividing into five tendons inserted into the last joints of the toes. A short extensor arises from the entire anterior surface of the bones of the tarsus: its tendons unite with those of the long extensor. The short flexor arises from the ankle joint, and giving off fleshy fibres to the tendons of the long flexor. There is likewise a special extensor and abductor of the great toe, and a similar one appropriated to the little toe. Both these arise from the ligaments of the tarsus. External and internal interossei muscles are likewise present.

The other muscles represented in the adjoining figures are the sphincter ani (42), and a flexor of the tail (43), derived from the transverse processes of the caudal vertebræ.

The Teeth. — The dental apparatus of the Reptilia is so widely different in its construction in the different orders and even genera of this class of animals, that no general description of it is possible. We shall therefore quote Professor Owen's * account of the various arrangements adopted in the principal groups into which they have been divided by naturalists.

In the Deirodon scaber, the inferior spinous processes of certain of the cervical vertebræ are unusually prolonged, and penetrate the

* Owen's Odontography, page 179, et seq.

coats of the œsophagus: their extremities, which are thus introduced into the alimentary canal, are coated with a layer of hard dentine, and form substitutes for the teeth, which, if not always entirely absent, are merely rudimental in the ordinary situations in the mouth.

In the tortoises and turtles the jaws are covered, as is well known, by a sheath of horn, which in some species is of considerable thickness, and very dense; its working surface is trenchant in the carnivorous species, but variously sculptured and adapted for both cutting and bruising in the vegetable feeders.

The development of the continuous horny maxillary sheath commences, as in the parrot tribe, from a series of distinct papillæ, which sink into alveolar cavities, regularly arranged (in Trionyx) along the margin of the upper and lower jaw-bones. These alveoli are indicated by the persistence of vascular canals long after the originally separate tooth-like cones have become confluent and the horny sheath completed.

The teeth of the dentigerous Saurian and Ophidian reptiles are, for the most part, simple, and adapted for seizing and holding, but not for dividing or masticating their food.

In no reptile are the teeth reduced to so small a number as in certain mammals and fishes, nor are they ever so numerous as in many of the latter class. Some species of Monitor (*Varanus*) with sixteen teeth in the upper and fourteen in the lower jaw, afford examples of the smallest number in the present class. It is rarely that the number of teeth is fixed and determinate in any reptile so as to be characteristic of the species.

The teeth may be present on the jaws only, as in the Crocodiles and many Lizards; or upon the jaws, and roof of the mouth, and here either upon the pterygoid bones, as in the Iguana, or upon both palatine and pterygoid bones, as in most serpents. As a general rule, the teeth of reptiles are anchylosed to the bone which supports them. When they continue distinct, they may be lodged either in a continuous groove, as in the extinct Ichthyosaur, or in separate sockets, as in the Crocodilians. The base of the tooth is anchylosed to the walls of a moderately deep socket, in the extinct Megalosaur and Thecodon. In most Ophidians, and in the Geckos, Aganuans, and Varanians, the base of the tooth is imbedded in a shallow socket, and confluent therewith. In the Scincoidians, Safe-guards (*Tejus*), in most Iguanians, in the Chameleons, and most other Lacertian reptiles, the tooth is anchylosed by an oblique surface extending from the base more or less upon the outer side of the crown to an external alveolar plate of bone, the inner alveolar plate not being developed.

The lizards which have their teeth thus attached to the side of the jaw are termed Pleurodonts. In a few Iguanians, as the Istiures, the teeth appear to be soldered to the margins of the jaws: these have been termed Acrodonts. In some extinct Lacertians, as the Mososaur and Leiodon, the tooth is fixed upon a raised conical process of bone.

The completion of a tooth is soon followed by preparation for its removal and succession. The facility of developing new tooth germs seems to be unlimited in the present class, and the phenomena of dental decadence and replacement are manifested at every period of life. The number of teeth is generally the same in each successive series, and the difference of size presented by the teeth of different and distinct series is considerable.

The new germ is always developed, in the first instance, at the side of the base of the old tooth, never in the cavity of the base: the crocodiles form no exception to this rule. The poison fangs of serpents succeed each other from behind forwards; in almost every other instance, the germ of the successional tooth is developed at the inner side of the base of its predecessor.

As the tooth acquires hardness and size, it presses against the base of the contiguous attached tooth, causes a progressive absorption of that part, and finally undermines, displaces, and occupies the position of its predecessor.

In the crocodile the tooth-germ is developed from the vascular membrane covering the base of the internal wall of the socket. It is soon invested by a capsule, and by its pressure causes the formation of a shallow recess, or secondary alveolus, in the contiguous bone. In this alveolus, however, it never becomes inclosed like the successional teeth in most mammalia; for, exerting equal pressure against the fang of the contiguous tooth, which, from being incompletely formed, has a wide pulp cavity with very thin walls, the nascent tooth soon penetrates that cavity, and quits the recess in the alveolar plate, in which it was originally situated. Thus the stage of development corresponding with the eruption of the tooth in the mammalia is immediately followed by the inclusion of the new tooth in the pulp cavity of its predecessor. The rapid succession of tooth germs, which stamps the impress of decay upon their predecessors often before the growth of these is completed, though common to many reptiles, is most strikingly manifested in the crocodiles, in which three and sometimes four generations of teeth, sheathed one within the other, are contained in the same socket.

The order Ophidia, as it is characterised in the system of Cuvier, requires to be divided into two sections, according to the nature of the food, and the consequent modification of the jaws and teeth. Certain species, which subsist on worms, insects, and other small invertebrate animals, have the tympanic pedicle of the lower jaw immediately and immoveably articulated to the walls of the cranium. The lateral branches of the lower

jaw are fixed together at the symphysis, and are opposed by the usual vertical movement to a similarly complete maxillary arch above: these belong to the genera Amphisbœna and Anguis of Linnæus. The rest of the Ophidians (true serpents), which form the typical members, and by far the greatest proportion of the order, prey upon living animals of frequently much greater diameter than their own; and the maxillary apparatus is conformably and peculiarly modified to permit of the requisite distention of the soft parts surrounding the mouth, and the transmission of their prey to the digestive cavity.

The two superior maxillary bones have their anterior extremities joined by an elastic and yielding fibrous tissue, with the small and single intermaxillary bone; the symphysial extremities of the lower maxillary rami are connected together by a similar tissue, allowing of a still wider lateral separation. The opposite or posterior extremity of each ramus is articulated to a long and moveable vertical pedicle, formed by the tympanic or quadrate bone, which is itself attached to the extremity of a horizontal pedicle formed by the mastoid bone, so connected as also to allow of a certain yielding movement upon the cranium. The palatine and pterygoid (*d*) bones have similar loose and moveable articulations, and concur with the other dentigerous bones of the mouth in yielding to the pressure of the large bodies with which the teeth may have grappled.

With the exception of the Deirodon scaber and some congeneric species, in which the teeth of the ordinary bones of the mouth are so minute as to have been deemed wanting, the maxillary and premandibular in all true Ophidians are formidably armed with sharp-pointed teeth; there is on each side the palate a row of similar teeth supported by the palatine and pterygoid bones. In the great Pythons, and some species of Boa, the intermaxillary bone also supports teeth.

All the teeth, whatever be their position, present a simple conical form; the cone being long, slender, and terminated by an acute apex; and the tooth is either straight, or more commonly bent a little beyond the base, or simply recurved, or with a slight sigmoid inflection. The teeth are thus adapted for piercing, tearing, and holding, and not for dividing or bruising. In some species, certain teeth are traversed by a longitudinal groove for conveying an acrid saliva into the wounds which they inflict: in others, two or more teeth are longitudinally perforated for transmitting venom; such teeth are called poison fangs, and are always confined to the superior maxillaries, and are generally placed near the anterior extremity of those bones.

In the genus *Deirodon* the teeth of the ordinary bones of the mouth are so small as to be scarcely perceptible; and they appear to be soon lost, so that it has been described as edentulous. An acquaintance with the habits and food of this species has shown how admirably this apparent defect is adapted to its well-being. Its business is to restrain the undue increase of the smaller birds by devouring their eggs. Now if the teeth had existed of the ordinary form and proportions in the maxillary and palatal regions, the egg would have been broken as soon as it was seized, and much of its nutritious contents would have escaped from the lipless mouth of the snake in the act of deglutition; but, owing to the almost edentulous state of the jaws, the egg glides along the expanded opening unbroken; and it is not until it has reached the gullet, and the closed mouth prevents any escape of the nutritious matter, that the shell is exposed to instruments adapted for its perforation. These instruments consist of the inferior spinous processes of the seven or eight posterior cervical vertebræ, the extremities of which are capped by a layer of hard cement, and penetrate the dorsal parietes of the œsophagus: they may be readily seen, even in very young subjects, in the interior of that tube, in which their points are directed backwards. The shell being sawed open longitudinally by these vertebral teeth, the egg is crushed by the contractions of the gullet, and is carried to the stomach, where the shell is no doubt soon dissolved by the acid gastric juice.

In the *Boa Constrictor* the teeth are slender, conical, suddenly bent backwards and inwards above their base of attachment, with the crown straight curved, as in the posterior teeth. The intermaxillary bone supports four small teeth; each superior maxillary bone has eight much larger ones, which gradually decrease in size as they are placed further back; there are eight or nine teeth of similar size and proportions in each premandibular bone. These teeth are separated by wide intervals, from which other teeth similar to those in place have been detached. The base of each of the above teeth is extended transversely, compressed antero-posteriorly, and anchylosed to a shallow alveolus, extending across the shallower alveolar groove. An affinity to the lizard tribes is manifested by the greater development of the outer as compared with the inner wall of the alveolar furrow.

The palatine teeth, of which there are three or four in each palatal bone, are as large as the superior maxillary, and are similarly attached: the pterygoid teeth, five or six in number, which complete the internal dental series on the roof of the mouth, are of smaller size, and gradually diminish as they recede backwards. In the interspaces of the fixed teeth in both these bones, the places of attachment of the shed teeth are always visible; so that the dental formula, if it included the vacated with the occupied sockets, would express a greater number of teeth than are ever in place and use at the same time. In the smaller species of boa the intermaxillary bone is edentulous.

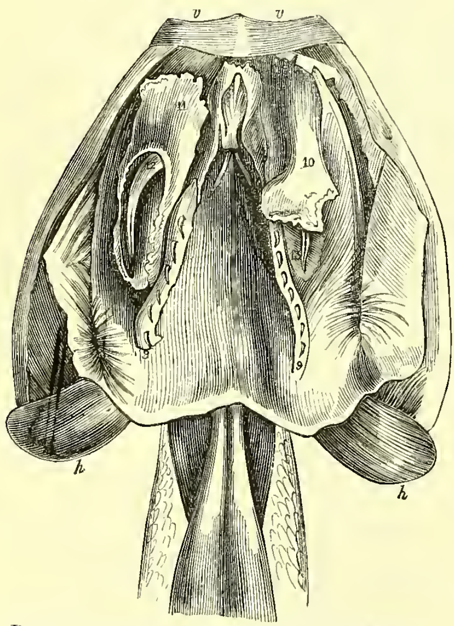
In certain genera of the non-venomous serpents, as *Dryophis*, *Dipsas*, and *Bucephalus*,

in which the superior maxillary teeth increase in size towards the posterior part of the bone, the large terminal teeth of the series are traversed along their anterior and convex side by a longitudinal groove. In the *Bucephalus capensis* the two or three posterior maxillary teeth present this structure, and are much larger than the anterior teeth, or those of the palatine or premandibular series; they add materially to the power of retaining their prey, and may conduct into the wounds which they inflict an acrid saliva, but they are not in connexion with the duct of an express poison gland. The long grooved fangs are either firmly fixed to the maxillary bones, or are slightly moveable, according to their period of growth: they are concealed by a sheath of thick and soft gum, and their points are directed backwards. The sheath always contains loose recumbent grooved teeth, ready to succeed those in place.

In most of the Colubri each maxillary and premandibular bone includes from twenty to twenty-five teeth; they are less numerous in the genera Tortrix and Homalopsis, and are reduced to a still smaller number in the poisonous serpents, in the typical genera of which the short maxillary bone supports only a single perforated fang.

In the poisonous serpents the superior

Fig. 209.



Roof of the mouth of the Rattlesnake, showing the Series of palatine Teeth.

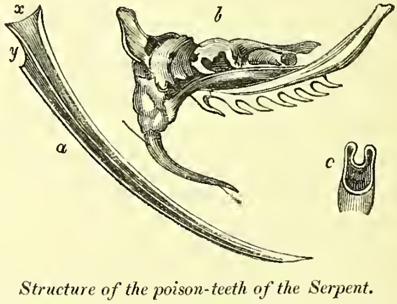
The sheath of the poison fang (11), opened to show the poison fang (12). On the opposite side the sheath (10) is represented entire; *h h*, external pterygoid muscles; *v v*, anterior adductor muscle of the rami of the lower jaw.

maxillary bone diminishes in length with the decreasing number of teeth which it supports. The transverse or external pterygoid bone elongates in the same ratio, so as to retain its position as an abutment against the shortened maxillary, and the muscles implanted into this external pterygoid style communicate, through it, to the maxillary bone the hinge-like movements backwards and forwards upon the ginglymoid articulations connecting that bone with the anterior frontal, and palatine bones. As the fully-developed poison fangs are attached by the same firm basal anchylosis to shallow maxillary sockets, which forms the characteristic mode of attachment of the simple or solid teeth, they necessarily follow all the movements of the superior maxillary bone. When the external pterygoid is retracted, the superior maxillary rotates backwards, and the poison fang is concealed in the lax mucous gum, with its point turned backwards. When the muscles draw forward the external pterygoid, the superior maxillary bone is pushed forwards, and the recumbent fang withdrawn from its concealment and erected.

The peculiar structure of the poison fang was first described by Fontana as it exists in the viper, and subsequently received additional elucidation by Mr. Smith's careful examination of the fangs of the Hydrus, Naja, and Crotalus, and by Mr. Clift's illustrative drawings appended to Mr. Smith's Paper. A true idea of the structure of a poison-fang will be formed by supposing the crown of a simple tooth, as that of a Boa, to be pressed flat, and its edges to be then bent towards each other, and soldered together, so as to form a hollow cylinder open at both ends.

The flattening of the fang, and its inflection around the poison-duct, commences immediately above the base, and the suture of the inflected margins runs along the anterior and convex side of the recurved fang; the poison canal is thus in front of the pulp cavity. The basal aperture of the poison canal is oblique, and its opposite outlet is still more so, presenting the form of a narrow elliptical longitudinal fissure, terminating at a short distance from the apex of the fang. The relative position of the two apertures of the poison canal is shown in the figure of the

Fig. 210.



Structure of the poison-teeth of the Serpent.

a, longitudinal section of poison fang; *b*, shows a hair inserted into the poison canal; *c*, transverse section of fang.

fang of the large cobra (*fig.* 34.), where a fine hair is represented as passing through the poison canal: in figure (a) the relative position of the pulp cavity (x) to the poison canal (y) is shown in the plan of a longitudinal section of a poison fang.

The colubriform poisonous serpents of the land have comparatively short venom-fangs, but they are larger than those of the pelagic serpents; and behind the venom-fangs there are likewise some smaller grooved teeth in the maxillary bones: there are three such teeth in the Bungarus pama, and five in the Bungarus annulatus. In the Hamadryas, or great hooded poisonous tree-snake of India, the venom-fang is relatively as large as in typical poisonous serpents, but three or four smaller grooved teeth are implanted behind it on the maxillary bone.

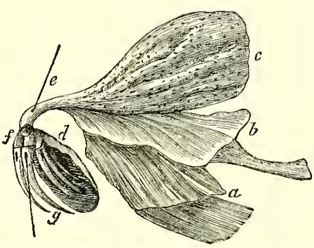
In the most deadly venom-snakes, as the viper (*Berus*), the puff adder (*Vipera*), the asps, or hooded snakes (*Naja*), the rattlesnakes (*Crotalus*), the cophias and fer-de-lance (*Trigonocephalus*), the poison fangs acquire their largest size, and are associated only with their successors: these are clustered in greater or less number behind them, presenting the same structure, but of a size proportionate to their degree of development, and further differing in being loosely imbedded in the thick and wide mucous gum, which likewise conceals the fixed and functional fang in its ordinary position of retraction and repose. This fang is more strongly curved backwards than the ordinary teeth, but its acute and slender apex is frequently bent slightly in the contrary direction, as in the rattlesnake.

The poison glands occupy the sides of the posterior half of the head: each consists of a number of elongated narrow lobes, extending from the main duct which runs along the lower border of the gland upwards, and slightly backwards; each lobe gives off lobules throughout its extent, thus presenting a pinnatifid structure; and each lobule is subdivided into smaller secerning cæca, which constitute the ultimate structure of the gland. The whole gland is surrounded by a double aponeurotic capsule (b), of which the outermost and strongest layer is in connexion with the muscles (a), by whose contraction the several cæca and lobes of the gland are compressed and emptied of their secretion. This is then conveyed by the duct to the basal aperture of the poison canal of the fang. We may suppose, that as the analogous lachrymal and salivary glands in other animals are most active during particular emotions, so the rage which stimulates the venom-snake to use its deadly weapon must be accompanied with an increased secretion and great distention of the poison glands; and as the action of the compressing muscles is contemporaneous with the blow by which the serpent inflicts its wound, the poison is at the same moment injected with force into the wound from the apicial outlet of the perforated fang.

The duct which conveys the poison, although it runs through the centre of a great part of the tooth, is, nevertheless, as we have seen, really on the outside of the tooth, the canal in which it is lodged and protected being formed by a longitudinal inflection of the parietes of the pulp cavity or true internal canal of the tooth. This inflection commences a little beyond the base of the tooth, where its nature is readily appreciated, as the poison duct there rests in a slight groove or longitudinal indentation on the convex side of the fang: as it proceeds, it sinks deeper into the substance of the tooth, and the sides of the groove meet and seem to coalesce, so that the trace of the inflected fold ceases, in some species, to be perceptible to the naked eye; and the fang appears, as it is commonly described, to be perforated by the duct of the poison fang.

The poison canal again assumes the form

Fig. 211.



Poison Apparatus of the Viper (*Vipera Berus, after Brandt and Ratzburg*).

a, the muscle inserted into the capsule of the gland; b, the aponeurotic capsule laid open; c, the poison gland laid bare; d, capsule of the gum containing the supplementary fangs; e, a hair passed into the poison duct, and into the poison canal of the fang; f, g, anterior supplementary fang.

of a groove near the apex of the fang, and terminates on the anterior surface in an elongated fissure.

Development of the Teeth.— In the black alligator of Guiana, the first fourteen teeth in the lower jaw are implanted in distinct sockets; the remaining posterior teeth are lodged close together in a continuous groove, in which the divisions for sockets are faintly indicated by vertical ridges, as in the jaws of the fossil Ichthyosaurus.

The tooth germ is developed from the membrane covering the angle between the floor and the inner wall of the socket. It becomes in this situation completely enveloped by its capsule, and an enamel organ is formed at the inner surface of the capsule before the young tooth penetrates the interior of the pulp cavity of its predecessor.

The matrix of the young growing tooth affects, by its pressure, the inner wall of the socket, and forms for itself a shallow recess: at the same time it attacks the side of the base of the contained tooth: then, gaining a more extensive attachment by its basis and increased size, it penetrates the large pulp cavity of the previously formed tooth, either by a circular or semi-circular perforation.

The size of this perforation in the tooth and of the depression in the jaw, compared with that of the calcified part of the tooth matrix, proves them to have been, in great part, caused by the soft matrix, which must have produced its effect by exciting vital action of the absorbents, and not by mere mechanical force. The resistance of the wall of the pulp cavity having been thus overcome, the growing tooth and its matrix recede from the temporary alveolar depression, and sink into the substance of the pulp contained in the cavity of the fully formed tooth. As the new tooth grows, the pulp of the old one is removed: the old tooth itself is next attacked, and the crown, being undermined by the absorption of the inner surface of its base, may be broken off by a slight external force, when the point of the new tooth is exposed.

The new tooth disembarrasses itself of the cylindrical base of its predecessor, with which it is sheathed, by maintaining the excitement of the absorbent process so long as the cement of the old fang retains any vital connexion with the periosteum of the socket; but the frail remains of the old cylinder, thus reduced, are sometimes lifted out of the socket upon the crown of the new tooth, when they are speedily removed by the action of the jaws.

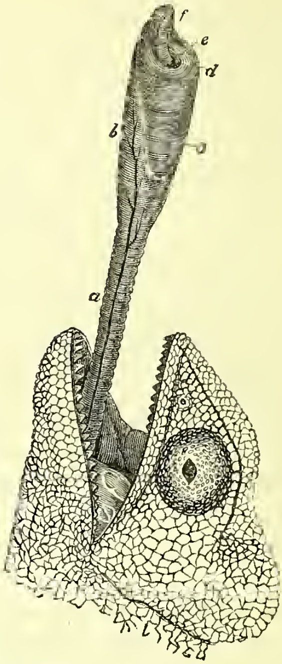
No sooner has the young tooth penetrated the interior of the old one, than another germ begins to be developed from the angle between the base of the young tooth and the inner alveolar process, or in the same relative position as that in which its immediate predecessor began to rise; and the processes of succession and displacement are carried on uninterruptedly, throughout the long life of these cold-blooded carnivorous reptiles

From the period of exclusion from the egg, the teeth of the crocodile succeed each other in the vertical direction; none are added from behind forwards, like the true molars in Mammalia. It follows, therefore, that the number of the teeth of the crocodile is as great when the animal first sees the light, as when it has acquired its full size; and, owing to the rapidity of their succession, the cavity at the base of the fully-formed tooth is never consolidated.

Tongue.—In reptiles the tongue can scarcely be regarded as an organ of taste, and indeed, seeing how little their teeth are adapted for mastication, and how very generally their prey is swallowed entire, such a sense could hardly be usefully accorded to them. The lingual apparatus is, therefore, variously modified in different genera, and converted into an instrument of prehension in some cases, whilst in others it seems to perform functions, the nature of which is not so obvious.

In the *Chelonian* reptiles the tongue is but little adapted to appreciate savours: it is covered with a thick rugose membrane, the surface of which in the turtles is smooth, but in some tortoises, as, for example, in the Testudo indica, it is remarkably beset with numerous elongated and pointed papillæ.

Fig. 212.



Tongue of the Chameleon partially extended.

a, slender extensible portion of the tongue; *b*, *c*, its bulbous extremity; *d*, *e*, *f*, prehensile apparatus at the end of the tongue.

Beneath the mucous membrane which covers this organ, there exists, in this order, a thick stratum of glandular follicles, whilst others situated beneath the tongue pour out their secretion through numerous ducts situated on each side of the frænum linguæ. The body of the os hyoides is cartilaginous, and from its extremity a glosso-hyal or lingual bone is prolonged into the substance of the tongue.

In those lizards which feed upon vegetable substances, the body of the tongue is fleshy, generally bifid at its extremity, and its surface is papillose. In some instances, as in the Iguana, its apex is tipped with horn. In other genera of lizards, which feed principally on insects, the extremity of the tongue is fissured, and the whole organ is remarkably extensible, forming an apparatus wherewith to catch their insect prey.

Perhaps in no animal is the tongue more remarkable than in the *Chameleon*, where by its extraordinary power of extension, and by the rapidity of its movements, it is made to compensate for the extreme sluggishness which characterises the muscular system of that animal. The chameleon, fixed firmly by means of its bifid feet upon the bough of a tree, and concealed as much as possible by adopting the colours of the branches around,

has no occasion to move in search of insect prey, but waits patiently until its victims approach sufficiently near to be within reach of its singularly constructed tongue; which, although ordinarily concealed within the cavity of the mouth, is capable of being elongated until it exceeds in length the whole body of the animal. No sooner does a fly approach within five or six inches of the chameleon, than the tongue is slowly protruded for the length of about an inch, so as to expose its thick fleshy extremity, the end of which is divided into two prominent lips, and copiously lubricated with a thick viscid secretion. The whole tongue is then launched out with a rapidity that is perfectly amazing, to the length of six or seven inches, and a fly glued to its extremity is brought into the creature's mouth so quickly that the eye can scarcely follow the movement.

The following is Mr. Hunter's description of the anatomy of the tongue of the chameleon. "The tongue of the chameleon consists of four parts: first, a long basis; second, a pulpy or bulbous part, at the tip of the tongue; third and fourth, elongating and contracting parts, which run almost through the whole length.

"The basis, or bony apparatus of the tongue, consists of an os hyoides and os linguæ, somewhat similar to that of a bird; therefore there is nothing very remarkable in their construction.

"The bulbous, or thick part at the end of the true tongue, is that part which is to manage the food when caught; it is the operator within the mouth, of which it is the pincher or catcher, from its being formed at the end into two opposite points, similar to the elephant's snout. This surface is rugous, and covered with a gelatinous slime.

"The basis and true tongue or tip are united by an elongated and contracting medium, which is very extensive. This length of tongue, its extension, and contraction, are very singular, and, if well understood, most probably very curious.

"The cause and mode of the contraction of its length are not uncommon. The elongation of the tongue in this animal is perhaps like nothing that we are acquainted with in an animal body.

"The apparatus for the purpose is a small rounded body which passes from the apex of the os linguæ (*glosso-hyal*) to the bulbous parts, and then through the centre of the bulb. The part between bone and bulb consists of two different substances; one a whitish substance, which is the firmest, and appears to be capable of keeping its form: the other is softer and more transparent. That part which passes through the bulb consists only of one substance, and appears to be a sheath for the reception of the os-linguæ.

"The first of these (*i. e.* the whitish firmer substance) appears to be composed of rings, or something similar, placed obliquely in contrary directions, so as to appear to be two spirals crossing one another. Whether the other, or softer substance, has any direction of fibres, I could not observe, but I suspect it is muscular. If I am right in my conjecture, and of its disposition, it will be no difficult thing to show how it may be elongated; for if these rings are placed transversely, they may be brought so near to one another as to shorten the whole very considerably; and if they allow of being placed almost longitudinally, they must of course lengthen it very considerably; and this position can be easily produced by muscles, which I take the pulpy substance to be.

"The contraction of the tongue is owing to a degree of elasticity, but this appears to be only in the cellular membrane, acting as an assistant to the muscular. The muscular contraction is owing to two muscles, one on each side of the tongue: each arises from the os hyoides, on the inside of the os linguæ, and passes along the side of the tongue to its bulbous part; but before it gets to the bulbous part, it spreads itself all round.

"In the centre of each of these two muscles passes a considerable nerve to the bulbous part, and also two arteries. When the two muscles act, they draw the tongue back upon the os-linguæ, which, as it were, passes through the middle elongator, then through the centre of the bulb, till the whole tongue is retracted. Although this middle body is drawn upon the os-linguæ, yet it does not appear to be hollow, like a pipe; it rather appears to be filled with a very ductile cellular membrane, as in every part of the elongating division of the tongue, in order to allow of the great difference in the situation of parts with respect to one another."

In the *Crocodiles*, the structure of the tongue is equally remarkable, but of a very different character. In these reptiles the tongue has no projecting or moveable extremity, being attached by its whole circumference to the rami of the lower jaw, insomuch that it was described by Aristotle as being entirely deficient. Its whole surface is covered over with a thick coriaceous skin, upon which may be seen the openings of innumerable glandular follicles situated beneath it. At the posterior part of the organ, close to the opening of the fauces, the broad anterior part of the hyoid cartilage supports a broad fold of the skin that covers the tongue, which can be applied like a valve against a corresponding fold of the palatal membrane that descends from the roof the mouth, so that the two, when approximated, form a valve that completely closes the communication between the mouth and the posterior fauces. By this arrangement the crocodile is enabled to keep its mouth open under water without danger of suffocation from that fluid getting into its trachea, whilst by means of its long tubular nostrils, which open at the very apex of its snout, and are continued backwards to behind the valvular apparatus above described, it is enabled to

breath with facility whilst only the tip of its

Fig. 213.

Throat, Œsophagus, and Stomach of the Crocodile.

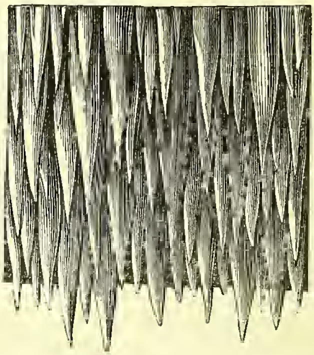
a, nostrils; *b*, postorbital plate; *c*, tongue; *d*, valves of the fauces; *e*, œsophagus; *f*, muscular portion of stomach; *i*, central tendons of ditto; *g—h*, commencement of duodenum.

nose is above the surface of the water, (*fig.* 213.)

Digestive System. — The œsophagus of reptiles is never dilated into a crop, as in birds; it either preserves nearly the same diameter throughout its entire length, or, if its capacity varies, it is insensible, and not by any sudden dilatation. But its diameter is generally much greater relative to the stomach, than in Mammalia or birds. In the Ophidians it is even more capacious than the stomach, at least when the latter is not distended with food: this happens because the walls of the stomach are more muscular than those of the œsophagus, and, consequently, contract more forcibly. When the œsophagus gradually dilates as it approaches the stomach, it often becomes difficult to say where one terminates and the other begins, and, consequently, to assign the situation of the cardia. The stomach is generally without any cul-de-sac, and its form much elongated. Most reptiles living upon prey have the digestive apparatus, and more particularly the stomach, of carnivorous animals. The latter viscus is always single, never multiple; its cavity being simple, never complicated. Even in those reptiles that feed on vegetable substances, the same plan of organization is retained, very slightly modified by such opposite habits.

The œsophagus of some Chelonian reptiles

Fig. 214.



Horny Processes in Œsophagus of Turtle.

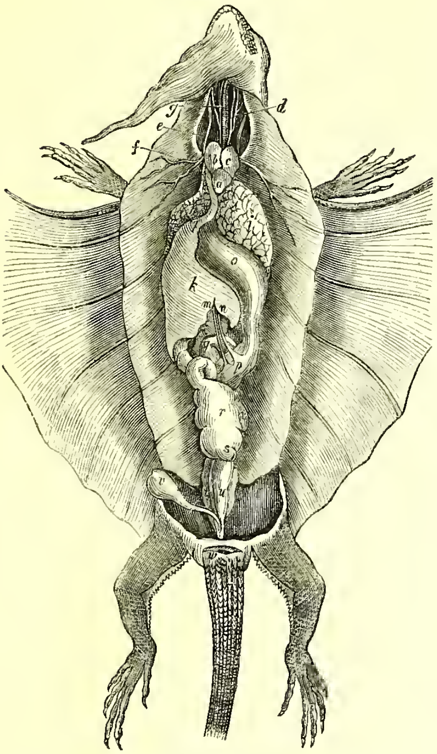
presents internally its whole inner surface crowded with long, hard, conical papillæ (*fig.* 214.), the points of which are directed backwards towards the stomach, and doubtless serve to prevent the return of substances swallowed towards the mouth. The muscular coat is generally very strong.

The stomach is generally of an elongated form and cylindrical shape; its longest portion is directed backwards; it then suddenly bends at an angle, and runs forwards. The second portion, which terminates at the pylorus, is always shorter than the first; its muscular coat is thicker than in the cardiac portion, and its lining membrane here forms longitudinal folds, which are more numerous and distinct. The pylorus is indicated by a circular elevated ring, which is sometimes very thick, or else by a fold.

Generally the walls of the stomach in the Chelonian reptiles are thick, partly owing to the strength of the muscular tunic, partly to the thickness of the mucous and cellular coats, the latter being penetrated by numerous crypts.

The stomach is closely connected with the liver, and in some species, as, for ex-

Fig. 215.



Draco volans.

a, ventricle of the heart; *b*, the right auricle; *c*, the left auricle; *d d*, carotid arteries; *e e*, the vena jugularis; *f f*, the subclavian artery; *g*, the trachea; *h*, the right lung; *i*, the left lung; *k*, the liver; *l l*, the lower venous sinus, which commences from the liver and extends to the right venous sinus; *m*, the biliary duct; *o*, the stomach; *p*, the commencement of the small intestine; *q q q*, the windings of the small intestine; *r*, the commencement of the large intestine; *s*, its attenuated region; *t t*, the kidneys; *u*, the cloaca; *v*, the bladder; *w*, the anus.

ample, in *Emys concina*, absolutely imbedded in its substance.

The diameter of the small intestine in the *Chelonians* gradually diminishes from the pylorus to its termination in the large intestine, the diameter of which is much larger, and its extremities much thicker. The parietes of the whole intestinal canal are indeed thicker than in most other reptiles. The calibre of the intestine is uniform throughout, and its lining membrane presents folds of variable breadths in different species, which are generally united together so as to form a kind of net-work at the commencement of the small intestine, but subsequently these become longitudinal and parallel. In the large intestines these folds become less regular in their arrangement.

It may be added to the above general description, that the alimentary canal of the reptiles belonging to this order presents differences in each genus, and even in some species of the same genus, which are in relation with corresponding differences in the nature of their food. The tortoises and the turtles, which live principally upon herbs or fuci, have the intestinal canal long; the large intestine longer than the small; the latter being inserted into the former laterally, so as to leave a small cæcum behind the point of entrance.

In the different species of Emydes, which are more carnivorous in their habits, and in the Trionyx, the alimentary canal is shorter — at least the large intestine, which is not longer than the small; and the latter is continuous with the large intestine, without there being any insertion of one into the other.

The *Crocodilidæ* differ from all other saurian reptiles in the form of their œsophagus and stomach.

The œsophagus is a narrow canal, easily distinguishable from the stomach on account of the globular form of the latter, and also by the different structure of mucous and cellular coats, the former of which is plicated and villous in the œsophagus, while the latter is very thin, and hardly perceptible.

The stomach is a great rounded globular cul-de-sac (*fig.* 213.), into which the œsophagus opens, at no great distance from the pylorus.

Close to this insertion there is, inferiorly, a small cul-de-sac (*g*), the cavity of which is separated from the larger cul-de-sac by a narrow passage, and which opens into the intestine by a constricted orifice. Necessarily, alimentary substances must pass through this channel into the pyloric cul-de-sac, in order to escape from the stomach. This structure evidently corresponds to the pyloric portion of the stomach in ophidian reptiles, to be described hereafter.

Generally, the parietes of the stomach are very strong; the mucous lining is smooth, thick, and very glandular, forming here and there broad folds, which run in a serpentine manner, like the convolutions of the brain. The cellular tunic, which was not very distinct in the œsophagus, becomes so in the stomach, whilst the muscular coat almost equals in thickness that of the cellular and mucous tunics combined: it is principally composed of fasciculi, which radiate from the centre towards the circumference, arising from an aponeurotic disc, which exists on both the abdominal and dorsal aspects of the organ. This stomach very nearly resembles the gizzard of a bird; and the resemblance becomes more striking if it be compared with the gizzard of a heron, the walls of which are thin, and which also opens into a little appendage.

The small intestine in the Nilotic crocodile may be distinguished into two portions: the first of these is wide, with thin walls, and is bent four times upon itself, so as to make four permanent folds: this portion is equal in length to about four-tenths of the whole

length of the intestine, and corresponds to the duodenum of birds. The other part is of smaller diameter, and has thicker walls, enclosing between the mucous and muscular tunics a layer of glandular substance, resembling a greyish, semitransparent pulp. The lining membrane of the intestine which covers this glandular layer is disposed in longitudinal zig-zags, connected together by little folds that pass from one to another, so as to constitute a fine net-work. These zig-zags are replaced by delicate villosities in the first portion of the small intestine, where the glandular layer is not perceptible; and towards its termination in the large intestine, they become reduced to undulating folds, rarely joined together by transverse plicæ. In the larger intestine itself, they are converted into irregular projections, which form a sort of villous surface.

In the other families of saurian reptiles, the form and structure of the stomach may be referred to the common type which we have already seen in the Chelonians. The œsophagus is wide, with very extensive walls, as is indicated by the longitudinal folds of its lining membrane; it is generally of the same diameter with the stomach, which latter forms a cylindrical or conical bowel, directed from before backwards, and generally bent a little towards the right near its termination, so that we may distinguish a pyloric portion extending from the bend to the pylorus, the length of which is very variable, and which is distinguishable from the rest of the stomach by the greater thickness of its coat. At the entrance of the duodenum there is a prominent muscular ring, serving the office of a pyloric valve.

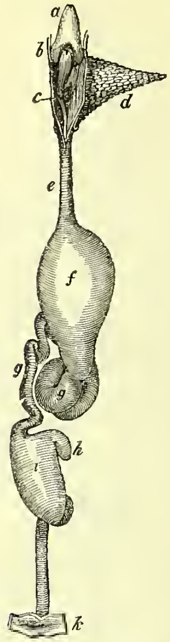
The great curvature, which is generally more dilated, is sometimes, though rarely, prolonged into a small cul-de-sac (*Monitor of the Nile*).

The small intestine of the *Lacertidæ* is short and sometimes very capacious in the first half of its extent; the other half presents ligamentous bands, which produce puckerings and constrictions corresponding internally with transverse ridges that intersect the oblique folds of the lining membrane. This latter in the large intestine forms transverse valves, dividing its cavity into numerous pouches.

The *Iguanas*, which live entirely upon fruits, grains, and leaves, have no cæcum, properly so called, indicative of this regimen; but their large intestine is prodigiously developed, and its cavity extended by numerous internal folds of the lining membrane.

In the *Ophidian reptiles*, the œsophagus and stomach form a continuous canal of variable length, in which it is generally difficult to say where the one terminates and the other begins; it may be remarked, however, that the walls of the œsophagus are thin, and the longitudinal folds of its lining membrane small and few in number, whilst the commencement of the stomach is indicated externally by a strengthening of the muscular fasciculi, and internally by thicker and more numerous longitudinal plicæ of the lining tunic, which are often undulating, and here and there irregular. These folds are only visible when

Fig. 216.



Alimentary canal of Draco viridis.

a, tongue; *b*, larynx; *c*, opening leading into the guttural sac; *d*, laryngeal sac, *e*, œsophagus; *f*, stomach; *g*, *g*, small intestine; *h*, cæcal appendage to the commencement of the colon; *i*, colon; *k*, the cloaca.

the stomach is empty. Sometimes the cardiac commencement of the stomach is indicated by a kind of cul-de-sac.

The stomach of serpents is remarkably short in relation to the length of the animal and the extent of the œsophagus; its situation also is very far back, so that the prey which the animal swallows will be lodged partly in the œsophagus and partly in the stomachal cavity. The latter may be divided into two portions, one of which Cuvier calls the "*sack*" and the other the pyloric portion. The "*sack*" has a very different appearance when empty to that which it presents when distended with prey: in the first case, its walls appear thick and muscular, whereas in the second they are very thin and extensible.

Before terminating in the intestine, the stomach becomes considerably diminished in its diameter, and is converted into a narrow channel of variable length in different genera and even in different species, which is but little susceptible of dilation, and into which the food only passes after being digested in the first portion. This second division of the stomach may be continuous with the axis of the former; at other times it seems to be given off from one side. It may be more or less bent upon itself, or even form several curvatures in different directions, or pass straight into the intestine. When the stomach

is empty, the pyloric portion may be distinguished from the "*sack*" by the thinness of its walls and the absence of longitudinal folds in its mucous membrane, which latter become gradually obliterated as they approach the pylorus. At its termination, this portion of the stomach can hardly be distinguished from the commencement of the intestine, which it resembles both in the transparency of its coats and in its uniform diameter; generally, however, the walls of the intestine are thinner and more transparent than that of the pyloric portion of the stomach, and its diameter sensibly increased. Internally, there is a very perceptible difference in the structure of the mucous membrane lining the two, which, in the pyloric portion of the stomach, is arranged in small longitudinal rugæ, but in the duodenum has a shaggy or villous appearance. Generally there is a valve or circular fold separating the stomach from the intestine, but this is sometimes only represented by a prominent ring formed by the mucous and cellular coats, and occasionally is altogether wanting.

It is in that part of the stomach which Cuvier calls the "*sack*" that the digestion of food is accomplished. The pyloric portion forms a first obstacle to stop the prey, which descends to the bottom of the stomachal "sack," where the digestive process is most rapidly carried on, for it is here that the dissolution of the animal swallowed always commences. In proportion as this dissolution goes on, the pyloric canal, the diameter of which is always very small, allows the digested portions of food to pass successively into the intestine.

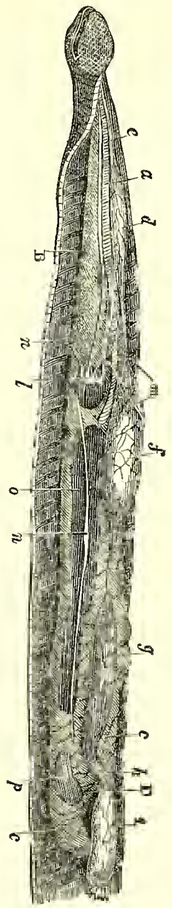
The intestinal canal in the common or ring-snake runs in an undulating manner from the pylorus to the rectum, preserving pretty nearly the same diameter throughout its whole extent, except that it dilates a little to form the colon. The lining membrane of the small intestine forms broad longitudinal laminæ, folded like a shirt-sleeve. In the large intestine, which runs straight to the cloaca, the folds are thick and irregular.

In the true serpents the arrangement is different: the first portion of the intestine forms numerous loops, more or less closely bent upon each other, and retained in position by bands of peritoneum passing between them. The whole is enveloped in a long cylindrical cell formed by the peritoneum.

This disposition of a part of the alimentary canal in the true serpents, distinguishes them from all other vertebrate animals; it seems to be rendered necessary by their manner of progressing upon their belly, which, without this precaution, might injure their intestines: it must, however, render slower the peristaltic movements, and thus contribute to produce the extreme lentor of all their digestive functions. This seems to be proved by the fact, that in water serpents (*Hydrus*, *Platurus*, *Chersydrus*) the intestine is a continuous cavity, and not divided into several loops, their movement in the water not requiring such arrangement.

In the Ophidian reptiles we may always distinguish a large and a small intestine; the

Fig. 217.



Viscera of the Rattlesnake.

a, the trachea; B, the right lung; *c*, bladder-like termination of ditto; *d*, *e*, *f*, the œsophagus; *g*, the stomach; *h*, commencement of the intestine, 1; *l*, the heart; *m*, large arterial trunks; *n*, *n*, anterior and posterior venæ-cavæ; *o*, the liver; *p*, the gall-bladder, situated at some distance from the liver.

latter generally terminates end to end in the former, and it is rare to find anything like a cul-de-sac or cæcum at the place of their union. The small intestine preserves nearly the same diameter throughout. The large intestine, which is shorter, is generally divided into two or sometimes three compartments by one or more sets of valves, or even by one or two partitions, through which there is only a small opening leading from one compartment to another. The first compartment is generally smooth, or only presents internally a few simple folds; whilst the last compartment, or the rectum, properly so called, has its cavity divided by irregular transverse plicæ, or even by very broad valvulæ conniventes. When there is an intermediate compartment, its sides are

smooth, or nearly so, like the first; but the communication between it and the third is always very narrow. Generally speaking, every arrangement seems to have been made to retard the passage of alimentary substances, and of the residue of digestion; or at least to prevent their passage from being too much accelerated by the act of creeping, and the contractions of the abdominal muscles necessary for its performance. The lining membrane of the small intestine is thrown into longitudinal folds of variable breadth, and more or less thick and numerous, which extend throughout its whole length, but which sometimes are connected together by transverse bands, so as to form cells. Sometimes these folds are beautifully fringed in the first portion, so as to give the mucous lining a villous appearance; and they have been observed quite white, with chyle filling their lacteal vessels.

The *liver* of reptiles is but indistinctly divided into lobes, and frequently is only irregularly notched upon its free border. Its relative size, in this class of animals, is very considerable. When the body is broad, it occupies a large proportion of both the hypochondriac regions; but when the body is elongated, it is situated in the right hypochondrium only, but extends very far back by the side of or beneath the intestines, in which position it is maintained by folds of peritoneum, resembling those which form the air-cells of birds.

In the *Chelonians* the liver is divided into two rounded irregular masses; one of which fills the right hypochondrium, whilst the other, which is connected with the smaller curvature of the stomach, extends into the epigastric and left hypochondriac regions: these two divisions are only connected together by two narrow processes, which bound a space through which the principal hepatic vessels pass.

In the crocodiles, whose digestive organs, in many respects, resemble those of birds, the liver consists of two distinct lobes, united together by a narrow central portion.

In the spectacled Caïman (*Crocodilus sclerops*), the right lobe is the largest, whilst the left is small and triangular. These two lobes separate anteriorly to receive the heart. The gall-bladder is always connected with the right lobe, but is here quite detached and separate from it,—a circumstance which holds good likewise in the Gavials; whilst in the Crocodile it is closely connected with the right lobe.

Among the *Lacertidæ*, the monitors have likewise two lobes to their liver, which are separated by a deep fissure. In the safeguards (*Ameiva*) this fissure is less decided, and the right portion of the viscus is prolonged backwards to a long, narrow, pointed appendage. This form conducts us gradually to the shape of the liver most generally met with in other Saurians, in which the organ consists of a single mass, rarely divided by deep fissures, but slightly notched at its margin. This mass is generally of a triangular shape, which is lengthened out in accordance with the form of the body, sometimes extending backwards quite to the posterior boundary of the abdominal cavity. In the *Ophidian reptiles* the liver is not divided into lobes, but forms a long cylindrical mass.

The *gall-bladder* is, in the Chelonian reptiles, almost entirely imbedded in the right lobe of the liver, and is generally of very great size; whilst in the Saurian reptiles it is generally situated at the bottom of the fissure which separates the two lobes. In the Ophidian reptiles, the position of the gall-bladder varies; in the genera Anguis, Amphisbœma, and Cecilia, it is more or less incrusted by the substance of the liver; but, in the true serpents, its position is very remarkable, for it is not only entirely separated from the liver, but is removed to a considerable distance from that viscus, and placed in the immediate vicinity of the pylorus.

In all reptiles the bile is conveyed into the gall-bladder by the branches of the *hepatic ducts*, which open either into its fundus, its neck, or into the commencement of the cystic canal: in the Chelonians, a very large proportion of the bile would seem to pass through the gall-bladder. In the Tortoises, which have the gall-bladder imbedded in their liver, the hepato-cystic vessels open immediately into its cavity. In the Emydes, the hepatic ducts unite to form a canal, which joins the neck of the gall-bladder.

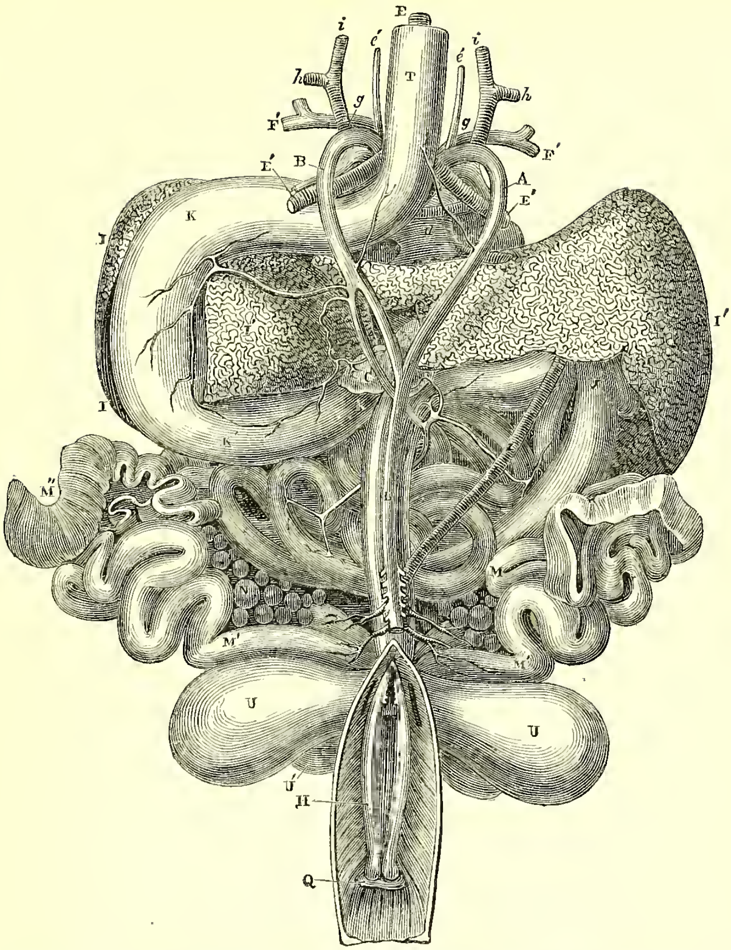
Amongst the Crocodiles, the spectacled caïman has its bile-ducts arranged almost in the same manner as in birds; the right hepatic canal opening immediately into the gall-bladder.

In the other Saurians, and also in Ophidian reptiles, the hepatic duct unites with the cystic, so that the gall-bladder is filled by the reflux of the bile; generally, there is only one hepatic duct, but in other cases there are several, which enter the cystic duct near the neck of the gall-bladder, as, for instance, in Trigonocephalus.

The *pancreas* is present in all reptiles, and is generally situated close to the point where the stomach terminates in the intestine, to which it is most generally adherent. In the Chelonians its shape is irregularly triangular, being narrow and thin in the vicinity of the pylorus, broad and bifurcated at its opposite extremity, by which it adheres to the spleen and to the large intestine. In the Saurians it is generally placed close to the pyloric portion of the stomach, and is divided into two branches, one of which accompanies the biliary canal; the other adheres to the spleen. These two branches unite in the vicinity of the pylorus, and furnish a duct which opens into the intestine along with that of the gall-bladder, which not unfrequently is imbedded in the substance of the pancreas. A similar disposition occurs in all the Ophidian genera.

The *spleen* is in the Reptilia always present, but its relations with the stomach are by no means so constant as in birds and Mammalia.

Fig. 218.



Viscera of the Female Tortoise. (*Emys Europæus.*) *The Lungs and Lymphatic Vessels have been removed, to exhibit the Course of the principal Blood Vessels.*

A, arch of the right aorta; B, arch of the left aorta; C, the pancreas; E, trachea; E′, E′, right and left bronchus; F′, F′, right and left subclavian arteries; H, the clitoris, lodged in the cavity of the cloaca, showing the deep urethral groove running along its dorsum; I, I′, lobes of the liver; K, K′, the stomach; L, common trunk formed by the union of the right and left aorta; M″, M′, M′, the right and left oviducts; N, the ovarium; Q, termination of the urethral groove, at the extremity of the clitoris; U, U, supernumerary lateral bladders, opening by wide fissures into the cloaca on each side of the clitoris; U′, urinary bladder; X, the spleen; *d*, vena-cava inferior, opening into the right auricle of the heart; *e*′, *g*, *h*, *i*, trunks of the jugular and subclavian veins.

It is frequently connected with the commencement of the intestinal canal. This is the case in the *Chelonian reptiles* (*fig.* 218. X.), it is fixed to the duodenum, not far from the pylorus, behind the opening of the ductus communis choledochus, and the head of the pancreas (C). In the Trionyx it, together with the head of the pancreas, is inclosed between the layers of the mesentery; and in the Turtle is contained in the first loop formed by the duodenum, close to the pylorus. In the *Crocodile of the Nile* it is attached to the left side of that portion of the intestine which immediately succeeds the first loop; whilst in the Caïman it is placed between the layers of the mesentery adhering to the second intestinal loop, close to the pancreas. In *Lizards* its usual position is at the side of the stomach.

The spleen in *Ophidian reptiles* belonging to the genera Anguis and Cecilia, is situated rather behind than in front of the pancreas, close to the commencement of the intestine; but in all the true serpents it is situated in front of the pancreas, to which it is closely attached, or indeed sometimes imbedded in its substance, receiving from it numerous veins of large size, which sometimes appear to form a sinus between the two organs, which are moreover connected by fibrous bands, and bound down by the same folds of peritoneum.

The abdominal viscera of reptiles are retained *in situ* by numerous *mesenteric* folds, the

arrangement of which varies in different races. It must be remembered that throughout the entire class there is no diaphragm or other septum dividing the viscera of circulation and respiration from those of digestion, all being inclosed in a common cavity, lined by the pleuro-peritoneum, which gives off processes to inclose and to fix them as far as is necessary in their respective situations. In the tortoises, that portion of the mesentery which attaches the small intestines, does not come immediately from the vertebral column, and only forms the mesentery after having fixed the transverse colon by a meso-colon. This remarkable disposition depends upon the general arrangement of the pleuro-peritoneum, and the extent of the cavities that it forms for the lodgment of the lungs. The meso-rectum also is derived rather from the lateral regions of the pelvis than from its middle. There are, besides hepato-gastric laminæ, which pass from the liver to the stomach, hepato-duodenal laminæ, between the liver and the duodenum; transverse gastro-colic laminæ, which pass from the stomach to the transverse portion of the large intestine; and duodeno-colic layers connecting the duodenal loop with the ascending colon. On the right of the mesorectum, there is an expansion which descends from the dorsal portion of the abdominal walls to join the proper mesentery.

Lastly, the large intestine commences by a loop which is bound down by peritoneal laminæ.

In the *Saurian* reptiles, the mesentery is well developed, that portion which is connected with the large intestine, as well as that which sustains the small intestine, coming off from the vertebral column. There is no transverse mesocolon.

The pleuro-peritoneum of *Ophidian* reptiles presents some varieties in its disposition. In the Anguidæ, a mesentery is given off from the whole length of the front of the vertebral column anteriorly: this serves to suspend the œsophagus and stomach, furnishing likewise a mesenteric fold to each lung, and to the liver. After enveloping the liver it forms a suspensory ligament attached to the mesial line of the ventral aspect of the abdominal walls, so that the whole may be regarded as forming two bags connected together, both above and below, along the middle line of the body, and thus dividing the abdominal cavity into two compartments by a vertical septum, extending along its whole length.

In the Ceciliæ a similar disposition exists.

In the true serpents the pleuro-peritoneum forms a cell around the intestine, which contains likewise small omental folds loaded with fat: the intestine itself, moreover, is folded into numerous festoons connected to each other by fibro-cellular bands. The large intestine in serpents has no connexion with the stomach, or with the commencement of the intestinal canal, as is almost invariably the case in other vertebrata.

Lymphatic System.—The lymphatic vessels in reptiles appear to be completely destitute of valves, except at the points where they terminate in the veins; a circumstance which explains the facility with which they can be injected from trunk to branch.

In the *Chelonian* reptiles the lymphatics of the alimentary canal, especially those of the stomach and small intestine, form two principal layers, of which the inner one constitutes a very delicate net-work *, so thin as only to be well seen with a magnifying-glass, lying close to the inner surface of the intestine, interlaced amongst the blood-vessels, but easily distinguishable from their continuity.

The external layer is made up of larger branches, which are so numerous that they touch each other, and after a successful injection completely cover the intestine: they all affect a longitudinal direction, and have an undulated or wavy appearance.

The lymphatics of these two layers serve to form another net-work placed external to the last, made up of large confluent branches, which convey the lymph into the principal lacteal trunks of the mesentery, which latter form a fourth net-work, the meshes of which are very close and fine.

In the urinary bladder and the oviduct, the arrangement of the lymphatics is similar to the above.

In the lungs they form a superficial layer, made up of large trunks; and a deep-seated layer, composed of very fine branches.

The external net-work of the gall-bladder is made up of very small meshes; whilst that of the spleen, on the contrary, consists of large confluent trunks, resembling sinuses: the latter organ, however, has likewise a smaller deep-seated set of lymphatic vessels which accompany the ramification of the veins into its interior.

The lymphatics of the testicle have a ramified or arborescent arrangement, increasing in size as they pass from the outer to the inner margin of the organ, the branches forming numerous anastomoses amongst themselves.

The adipose tissue, situated between the peritoneum and the carapax, is full of lymphatic vessels. Those of the peritoneum are very small and numerous: their direction is generally from before backwards.

The liver seems to possess very few lymphatics, and these Panizza was unable to inject, as also those of the œsophagus.

Among the *Saurian* reptiles the lymphatics have been examined in the Caïman, and in several species of lizards. In the former, the cloaca, the rectum, and the intestinal canal inclose several net-works of lymphatic trunks, the form and disposition of which varies. There is one upon the inner surface, and another upon the outer surface, the meshes of which are very close, and the vessels much convoluted.

In the rectum, the lymphatics form two layers, one superficial, the other deep-seated; in the former the vessels are large and their

* Panizza Sopra il Sistema Linfatico dei Rettili, &c. Pavia, 1833. in fol. with six plates.

direction transverse, whilst in the latter the canals are smaller, and their course longitudinal.

In the small intestine, likewise, there are two layers of lacteal vessels, one superficial (the peritoneal), and the other deep-seated. There is, moreover, a third stratum, composed of very fine lymphatics, which penetrate as far as the villi of the mucous membrane of the intestine. In the stomach they are comparatively few in number.

The lymphatics of the lungs form a net-work, the meshes of which are scattered and are irregular; upon the heart they are very numerous, inclosing rhomboidal spaces.

In the green lizard the lymphatics form a beautiful plexus around the corpus cavernosum, and a complicated net-work upon the cloaca; but it is remarkable that Panizza was not able to inject the lymphatics of the limbs, nor those of the testicles or kidneys.

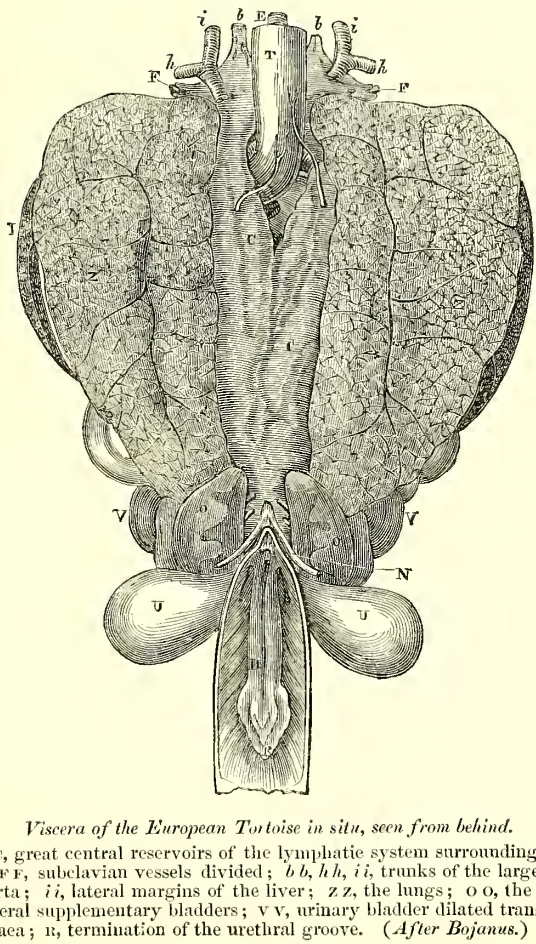
In *Ophidian* reptiles, the whole extent of the alimentary canal, with the exception of the œsophagus, is covered with lymphatic vessels, which are disposed in two layers, one deep-seated, made up of very delicate tubes, the other superficial, the vessels of which are larger.

The kidneys also are very rich in lymphatics.

The central parts of the lymphatic system of reptiles, corresponding with the *receptaculum chyli* and *thoracic duct* of mammalia, are extraordinarily capacious. They resemble, in fact, great serous cavities which are never entirely filled with lymph, but which establish a communication between the lymphatics of the viscera and other organs, and the veins situated in front of the heart. These reservoirs embrace the principal arteries, and even the veins that they encounter in their passage, covering them as with a sheath (*fig.* 219, C.). The lymphatics from the different organs, as they run towards these receptacles, form plexicose chains or detached branches, which are more or less knotty in their calibre.

In the *Chelonian* reptiles, according to Hewson, all the lymphatics derived from the hinder part of the body terminate in a plexus which surrounds the right aorta, and from thence open into a reservoir situated further forward beneath the left aorta. This latter

Fig. 219.



Viscera of the European Tortoise in situ, seen from behind.

E, the trachea; C C, great central reservoirs of the lymphatic system surrounding the principal arterial and venous trunks; F F, subclavian vessels divided; *b b*, *h h*, *i i*, trunks of the large vessels derived from the arches of the aorta; *i i*, lateral margins of the liver; Z Z, the lungs; O O, the kidneys; N, external iliac artery; U U, lateral supplementary bladders; V V, urinary bladder dilated transversely; H, the penis retracted into the cloaca; R, termination of the urethral groove. (*After Bojanus.*)

gives origin to two thoracic ducts, or rather to several principal trunks, which, as they advance, form two complicated plexuses, extending as far as the subclavian veins on each side, where they receive the lymphatics of the head, neck, and anterior extremities. On the right side, two branches pass from the plexus to open into the jugular vein, near its junction with the subclavian ; on the left side there is only a single lymphatic trunk, which opens into the jugular near the same point.

Among the *Saurian* reptiles the arrangement of the lymphatic system is as follows. In the pike-headed Caïman, there is a sacral plexus formed by the lymphatic vessels derived from the tail, and the posterior extremities under the vertebra, which represents the sacrum ; this plexus is continued along the aorta and the vena cava, the former vessel being in some places quite inclosed by it: this forms the principal reservoir of the lymphatic system. Opposite the third and fourth lumbar vertebræ, this reservoir receives the anterior trunks derived from the lateral pelvic plexuses, as well as those of the kidneys and of the loins ; it then runs forward and slightly to the left side, above the vena cava, where it receives the lymphatics of the mesenteric plexus.

Arrived opposite the conjunction of the two aortæ, this reservoir divides into four trunks, which represent the thoracic duct; these trunks unite and separate again several times as they advance forward: at last they form two fasciculi of vessels, which separate to the right and left, and terminate in the corresponding subclavian veins, having first received the lymphatics derived from the head and neck and anterior extremities.

In the green Lizards, the central reservoir of the lymphatics commences a little in front of the anus, by a cul-de-sac, which receives the lymphatics of the hinder extremities, of the kidneys, and of the rectum ; it then advances forwards in the abdomen, becoming considerably dilated, and collects the lymphatics of the small intestines, and partly those of the stomach. A little in front of the latter viscus there is a constriction which seems to indicate the limit between the reservoir and the thoracic duct. The latter vessel runs between the œsophagus and the vertebral column ; and afterwards between the latter and the left lung. Arrived at the heart, it divides into two diverging branches, which, running outwards, terminate in the anterior vena cava.

In the *Ophidian* reptiles the central lymphatic reservoir commences in front of the anus, and advances forward inclosed between the layers of the mesentery, between the intestines and the vertebral column ; becoming much enlarged as it advances forwards, and ultimately terminating in a conical cul-de-sac, opposite the commencement of the stomach. This reservoir receives the lymphatics from the tail, from the penis, from the kidneys, the testicles, the intestine, the stomach, and the dorsal region of the spine. A little before its termination in the cul-de-sac it gives off several branches, which, united into a single trunk, form the left thoracic duct. This runs forward between the stomach and liver, and subsequently between the liver and the œsophagus, to arrive at the region of the heart. The inferior or anterior right thoracic duct commences by a narrow cul-de-sac situated just behind the pancreas, and receives the lymphatics of the pancreatic plexus, as well as those from the spleen and gall-bladder. It runs forward above the vena porta and the vena cava; between the layers of the epiploon it receives three considerable branches from the right thoracic duct, and most of the lymphatics of the stomach; it then expands very considerably to envelope the stomach, and becoming again contracted beyond that viscus, it runs forward beneath the lung as far as the right side of the heart, near the entrance of the vena cava, into the pericardium, where it terminates by a cul-de-sac, after receiving several branches from the lungs.

Three other considerable lymphatic trunks, one mesial and inferior, the two others lateral, run along the whole length of the body from the head to the base of the heart, conveying into the cardiac plexus the lymph from all the anterior part of the body.

The cardiac plexus, which is situated in front of the base of the heart, is formed by the confluence of all the lymphatic trunks, forming as it were a central reservoir, being composed, first, of the three anterior lymphatic vessels mentioned above; secondly, by the left thoracic duct ; and, thirdly, by a trunk which combines the lymphatics of the lung and the right thoracic duct.

This reservoir opens into the anterior vena cava.

The lymphatic system of reptiles offers one peculiarity of structure which is very remarkable. Besides the usual termination of the principal lymphatic trunks in the venæ cavæ or in the axillary, subclavian, or jugular veins, it has been discovered that some lymphatic trunks open into small capsules which present alternate movements of contraction and dilatation, and which propel the lymph that they contain immediately into small contiguous veins: these capsules are therefore lymphatic hearts.

Such *lymphatic hearts* have been found to exist, both in the Saurian, Ophidian, and Batrachian orders of reptiles, the Chelonians only appearing to be without them. They are generally situated near the posterior extremity of the body, and discharge into the venous system the lymph derived from the most remote parts.

In the crocodile the lymphatic hearts are found on each side lodged between the upper border of the pelvis and the transverse process of the first caudal vertebra. They resemble elongated transparent bladders, and communicate with the veins of the kidney.

In the green lizard they occupy a similar situation, but they open into a vesicle that

empties itself into the principal vein of the corresponding hinder extremity.

The lymphatic hearts are in the snakes situated just above the origin of the tail. They communicate with a branch of the caudal vein, and receive lymphatic vessels from the posterior extremity of the great lymphatic reservoir.

In the Pythons, the situation of the lymphatic hearts is external to the abdominal cavity in a special chamber, which is bounded anteriorly by the last rib; each heart receives the lymph by three canals that open into its dorsal aspect, and it communicates with the caudal veins by two orifices situated at its anterior extremity. Each of these lymphatic hearts is composed of three membranes; an external one, which is cellular; a middle one, which is muscular, the muscular fasciculi being arranged as in the hearts of the higher animals; and an inner coat, which forms valvular folds, serving to prevent the escape of the venous blood into the lymphatic system.

These lymphatic hearts are without pericardium, and adhere to the walls of the cavity which contains them. In a Python Tigris of seven feet long, the length of each lymphatic heart was six lines, and its diameter four lines and a quarter.

Venous System. — The veins of reptiles have very thin walls, and exhibit no fibres in their structure, except in the large trunks of species of considerable size. In the Chelonians and the crocodiles they are furnished internally with a few valves, but these, it would appear, do not exist in the veins of Ophidians, at least they can be injected with facility in any direction.

As in other Vertebrata, the veins of reptiles are more numerous than the arteries, and from the frequency of their anastomoses represent rather a net-work than an arborescent arrangement. Their circulation, moreover, not being confined to a determinate course through the lungs, as in Mammalia and birds, the venous system in the Reptilia is never overloaded with blood, as must be the case in the two former classes, when respiration is suspended. And it is probably on this account that their veins appear less capacious, as compared with the arteries, than in those Vertebrata which possess a double circulation. For the same reason they are not dilated into reservoirs as they are in Mammalia and diving birds, or as in fishes, where the blood has but one route through the branchiæ.

The Chelonians have two *posterior venæ cavæ* which traverse the liver on each side and receive in their course a multitude of small hepatic veins. Immediately after issuing from the liver, they are each joined by an anterior vena cava of the corresponding side, or by the common trunk of the jugular and subclavian, all of them opening into a kind of reservoir, which communicates with the right auricle of the heart through a slit-like orifice guarded by two valves. The two veins called above posterior venæ cavæ are the umbilical veins of Bojanus, the analogues of the single abdominal or median vein of the Batrachian reptiles, which become confluent by winding towards each other and assuming a transverse direction in the isthmus that unites the lateral lobes of the liver: it is into this single transverse trunk that the two abdominal veins open.

Each abdominal vein communicates by a pectoral branch with an intercostal vein, and by this intermedium with a cervical branch from the jugular.

Each abdominal vein has, moreover, an anastomosis posteriorly with the inferior common intercostal; it is essentially a continuation from the iliac vein, which receives the blood from the femoral, from the iliac circumflex vein, from the ischiadic, from the caudal, from the hypogastric, and from the renal, through the descending trunk of the vena azygos. This latter, after anastomosing in front of the thorax with a cervical branch from the jugular, seems to convey the blood from before backwards, if we may judge from the gradual dilatation of its calibre, as it receives the intercostal veins, the muscular veins of the back, and the branches of the vertebral veins. Its trunk, as it descends towards the kidney, anastomoses with the vein derived from the generative organs, and joins the hypogastric to form the iliac: here, then, we have an arrangement of the venous system which determines the direction of the blood towards the liver, and makes the abdominal vein relatively to the liver what the pulmonary artery is to the lungs. A vein derived from the organs of generation, which, as already stated, anastomoses with the trunk of the vena azygos, likewise runs to the liver, traversing its right lobe like a vena cava, and in the same way receives many small hepatic veins and terminates immediately that it issues from the liver in the great sinus, common to the veins of the body.

Arterial System. — In reptiles there are always two distinct aortæ given off separately from the heart, and a third artery destined exclusively to the lungs.

In the *Chelonian* order, the two aortæ, together with the pulmonary artery, are united together for a little space; but the former soon separate to take the position and character, one of the right, and the other of the left posterior aortæ. The right aorta gives off, shortly after its commencement, a considerable artery, which might be called the anterior aorta, which soon bifurcates; each division again subdividing into two others, namely, the common carotid, and the subclavian.

The subclavian gives off almost the same branches as in the mammalia; namely, —

1. An artery analogous to the *inferior thyroid* of Mammalia, which supplies a very vascular cavernous little thyroid body, situated at the bottom of the neck.

2. The *common cervical*, which runs forwards under the neck internal to, and beneath the carotid, distributing branches to the muscles and other organs of the throat.

3. A little artery appropriated to the subclavian muscle.

The subclavian then bifurcates to form a large ascending branch, and a smaller external branch. From the ascending branch arise —

4. The superior cervical (vertebral of Bojanus) which supplies the muscles of the superior region of the neck, gives off some spinal branches, and at length becomes confounded with the cervical recurrent.

5. Two small spinal branches for the vertebræ of the neck.

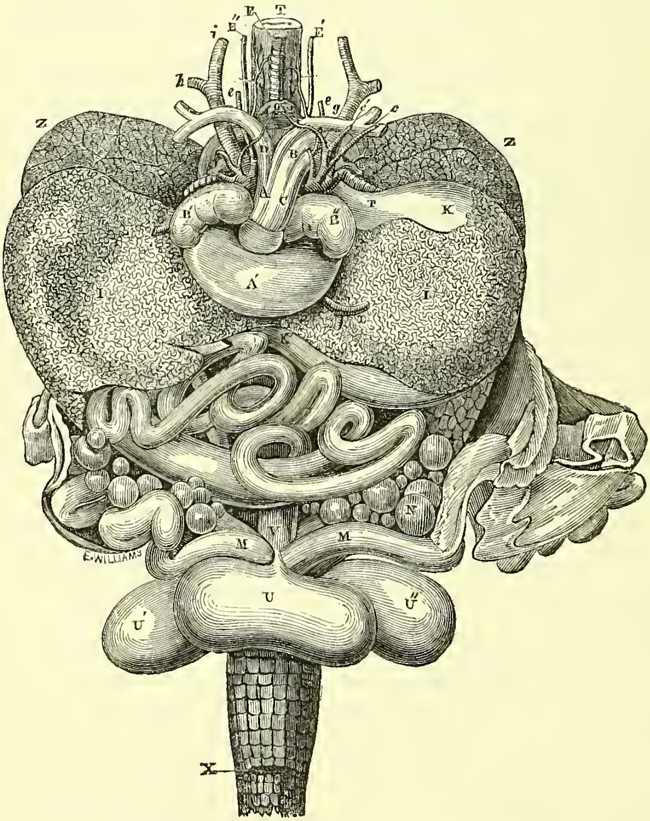
6. An intercostal branch, which divides to form the two anterior intercostals.

7. The ascending branch of the subclavian then turns downwards and backwards to form the analogue of the internal mammary, which runs along the external margin of the carapax, receives in succession the intercostal arteries, and ultimately becomes continuous with the epigastric.

8. The external branch, which is the continuation of the subclavian, gives off several arteries to the muscles of the shoulder, and to the great pectoral muscle, and then terminates by becoming the *axillary artery*, which, after giving off twigs to the muscles of the shoulder, becomes in turn the brachial artery. This latter immediately gives off three branches analogous to the *circumflex*, and to the *profunda humeri*. It then runs down, remarkably diminished in size, to the bend of the elbow, where it divides into two feeble trunks, the *radial* and the *ulnar*, the small size of which is proportionate to the small dimensions of the muscles and other parts of the fore-arm and hand: upon the palmar surface of the latter the ulnar artery forms an arch, as does the radial on its dorsal surface, and from these arches collateral branches are given off in the usual manner to supply the corresponding margins of the fingers.

Arteries of the Neck and Head.—The common carotid runs forward upon the side of the neck, hidden by the muscles connected with the os-hyoides, and in its course sends

Fig. 220.



Viscera of the Female Tortoise (*Emys Europæus*).

A′, ventricle of the heart; A, common trunk of the arterial system; B′, right auricle; B, left auricle; B, trunk of the right aorta; C, common trunk of the pulmonary arteries; D, trunk of the left aorta; E, trachea; E′ E″, carotid arteries; I I, right and left lobes of the liver; K, the stomach; K′, commencement of the intestinal canal; M M, terminations of the right and left oviducts; N, ovarium; T T, œsophagus; U, urinary bladder; U′ U″, right and left supernumerary bladders; X, external opening of the cloaca; V, the rectum; Z, the lungs; *c*, *e*, *g*, *h*, *i*, truncated vessels arising from the aorta.

branches to the œsophagus and neighbouring muscles, until it reaches the head, to which it is distributed without previously dividing into two principal branches, representing the two carotids of mammalia.

This difference doubtless depends upon the small size of the encephalon in these reptiles, and it may be remarked that the comparative smallness of the internal carotid, which is here only a subordinate branch of the external carotid, is not compensated by the size of the vertebral artery, which in the Chelonians does not exist. This last circumstance will not be surprising when it is remembered, that in birds the vertebral artery only supplies the muscles of the neck, the cervical vertebræ, and the spinal chord; furnishing in the cranium only a single small branch, which is entirely expended upon the medulla oblongata.

As in birds, the internal carotid of the Chelonians supplies all the parts of the encephalon.

There is a posterior communicating branch, which forms, in conjunction with its fellow, a basilar artery; which, as it is prolonged backwards beneath the spinal chord, forms an inferior median spinal artery. This last azygos artery gives off near its origin a recurrent branch, which is the superior lateral spinal.

The external carotid, which is the principal carotid trunk, resembles in its distribution very closely the external carotid of mammalia; it may, however, be remarked, that after giving off the lingual branch this artery penetrates into the temporal fossa through the external carotid canal, and that it there divides into two principal branches, one anterior, the other posterior; the former is appropriated exclusively to the head, and supplies the place both of the internal maxillary and of the temporal of mammalia.

The posterior branch of the carotid represents an occipital artery, of which the cervical branch is very greatly developed, so that this occipital seems to be transformed into a recurrent cervical artery, which runs backwards over all the dorsal region of the neck, giving branches to the muscles, to the vertebræ, and to the medulla spinalis, and ultimately anastomoses with the superior ascending cervical artery, derived from the subclavian. The quantity of blood which is thus furnished to the spinal chord of the neck by the recurrent and ascending cervical arteries is very remarkable.

Branches of the right posterior Aorta.—The two posterior aortæ, in the first instance, run upwards and outwards towards their respective sides, and then turning backwards approach each other so as ultimately to unite nearly opposite the fifth dorsal vertebra by a communicating branch which the left aorta furnishes to the right. Before, however, receiving this artery, the right aorta gives off several branches corresponding with the anterior intercostals.

After receiving the *communicating artery*, the right aorta runs backwards beneath the vertebral column as far as the pelvis, giving off in its course the following branches;—1st, five arteries on each side analogous to the intercostals; 2d, the spermatic; 3d, several renal branches to the kidneys on each side; 4th, several small lumbar branches; 5th, a small artery analogous to the posterior mesenteric, which is distributed to the cloaca; ultimately, the right posterior aorta terminates by four branches, namely, 1st, the left external iliac; 2d, the left internal iliac; and 3d, the common iliac of the right side. Between the two latter trunks arises the caudal artery analogous to the middle sacral. In the green turtle (*Chelonia Mydas*) the six last intercostals are given off immediately from the right aorta: but in the *Emys europea* their origin is very different, the five last intercostals being derived from a common anterior intercostal, which arises from the ascending branch of the subclavian. This vessel runs along the spine from before backwards, as is the case in many birds, and ultimately terminates by uniting with a posterior common intercostal: this latter is a branch derived from the iliac artery.

The divisions of the internal arteries resemble very closely what is found in mammalia. These vessels first separate into two branches, one of which gives off vessels to the bladder and to the cloaca; the other plunges into the pelvis, and apparently represents the ischiadic and posterior iliac arteries: the external iliac runs forward along the edge of the pelvis, giving off the analogue of the epigastric, from which arises the anterior iliac. Leaving the pelvis, the external iliac takes the name of crural, and after giving off the circumflex arteries, and the profunda femoris, continues its course, in all respects comparable in the remainder of its distribution to what is found in mammalia and birds.

The left (Visceral) Aorta.—The left aorta furnishes large arteries to the principal viscera of the abdomen, to which it is almost entirely distributed. As soon as it has passed the cardia it divides into three branches; of these the first, which is the smallest, furnishes a twig to the œsophagus, and is then distributed to the stomach, representing the coronary artery of mammalia.

The second, which is almost as large as the trunk from which it arises, supplies the intestines, the spleen, the pancreas, and the liver.

The third branch, intermediate in size between the two others, is the *communicating artery*, given off to join the right aorta, and from which no branches are furnished.

In the *Saurian* reptiles the distribution of the arterial trunks differs but little from that above described.

In *Lizards* the two aortæ advance forwards out of the thorax; that of the right side after dividing into three branches, that of the left without any such division. The left aorta winds backward upon the side of the neck, and afterwards runs along the vertebral

column, receiving at the point where it begins to take this direction from before backwards the left branch of the right aorta, which forms a loop in front of it. From the convexity of this loop arises the left carotid. The two other branches of the right aorta wind backwards, and join together in a similar manner upon the right side of the neck, forming two loops placed one in front of the other. The right carotid arises from the convexity of the loop. The subclavians are given off from each aorta a little before their union, except in crocodiles and the iguana, where they are both derived from the right aorta. The common trunk formed by the union of the two aortæ, which takes place just beyond the apex of the heart, gives off in succession numerous pairs of intercostal arteries. It sends, moreover, shortly after its commencement, an artery to the œsophagus, and subsequently a small branch to the liver; further backwards it gives off an artery which soon divides into two branches: of these the anterior supplies the stomach, the spleen, the pancreas, and the duodenum; the posterior, which represents the anterior mesenteric, is appropriated to the intestinal canal. The aortic trunk then gives off in succession the lumbar, the spermatic, the posterior-mesenteric, which supplies the rectum, and the renal, which are given off thus late because the kidneys are situated very far back in the abdominal cavity: lastly, it gives origin to the iliacs and the middle sacral arteries. The last-mentioned vessel may fairly be regarded as a continuation of the aortic trunk, from which the iliacs seem to be mere branches; a circumstance which is owing to the excessive proportions of the tail when compared with the extremities.

In the *Ophidian* reptiles, the absence of limbs, the existence commonly of a single lung, and the extremely slender and elongated form of the body, concur to render the distribution of the arterial trunks very simple throughout this order. These trunks, as in the Chelonians and Saurians, are three in number. Their first divisions, instead of being double and symmetrical, are reduced to single trunks. This is the case, for example, with the pulmonary artery in those serpents that possess but one lung, and also with the common carotid, and the vertebral in the entire order.

It is from the convexity of the right aorta, and very near its origin, that the above branches, destined to supply blood to the head and neck, are derived.

The right aorta then winds backwards, passes above the œsophagus, and then running obliquely inwards and backwards, it joins the left aorta at a little distance beyond the apex of the heart.

The right aorta gives off, a little after its origin, a small artery that supplies a small round glandular-looking mass situated in front of the base of the heart, and subsequently to another similar body of elongated form, situated beneath the jugular vein. It then gives off the common carotid, which is single in all the Ophidia. A third artery is given off a little further on, which is the common trunk of the vertebral and anterior intercostals. No other important artery is given off by the right aorta, and when it joins the left aorta its diameter is very small, so that the greater portion of the blood that this vessel receives from the heart is supplied to the organs which are situated in front of that viscus: it might therefore be properly named the carotid artery.

The *carotid artery* runs obliquely towards the left side, and advances forward, closely connected to the left jugular vein, between the trachea and the œsophagus, and at length is situated beneath the latter. It gives off a great number of small branches to these parts, and near the head divides into several small arteries, which represent both the external and internal carotids.

When the right aorta approaches the vertebral column, it gives off, as stated above, a considerable branch, which supplies the place both of the vertebral arteries and the anterior common intercostals. This artery advances beneath the vertebral column, giving off branches on both sides, opposite each intercostal space, both to the muscles and to the vertebræ of the region which it traverses, and only enters the vertebral column close to the head. This vertebral and intercostal artery likewise gives off recurrent branches, which furnish intercostal vessels behind its point of origin.

The *left aorta* runs upwards, backwards, and to the left side: passes beneath the œsophagus, and afterwards beneath the lung until it reaches beyond the apex of the heart, where it receives the right aorta, and continues its course backwards. It continually gives off branches corresponding to the intercostals and the visceral arteries: those which furnish the stomach, the liver, and the pulmonary sac or sacs, are given off successively from the aorta in its course backwards, so that there is nothing like cæliac axis. Nearly opposite the pylorus it gives off the anterior mesenteric, which runs parallel to the intestine for half its length, to which it constantly furnishes branches. Further backwards the intestinal canal receives in succession three other small branches from the aorta, which gives off as it runs backwards arterial branches to the kidneys, ovaries, and other viscera. Arrived at the termination of the abdomen, it passes on beneath the vertebræ of the tail, in which it becomes gradually expended.

Organs of Respiration.—In several species of *Lizards* the cavity of the fauces is much enlarged by an expansion of the skin in front of the larynx (*fig.* 216, *d.*). These laryngeal sacs, as they are called, appear to be receptacles for air rather than food; for, although not connected with the larynx, they are extraordinarily distended in rage, &c.

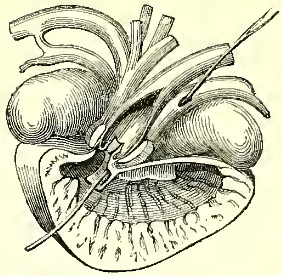
Before the termination of the trachea, both in the *Coluber natrix* and *thiringicus*, there is a small blind depression, which, as was first re-

marked by Nitzsch, may be considered a rudiment of the left lung. The right, and in this case sole, pulmonary sac is placed immediately below the spine; it extends posteriorly as far as the region of the kidneys, and in the Coluber natrix is from five to seven inches long, and from one-half to three-quarters of an inch broad. Its parietes are thickest at the point where the rings of the trachea cease, where it is covered externally by a fibrous layer, and lined internally by a fine lattice-like network of vessels. More posteriorly the parietes become gradually thinner, and at last are merely membranous, giving to the whole organ still more of the appearance of a swimming bladder. In the slow-worm (*Anguis fragilis*) there are two lungs, nearly as in the salamander, though the left is still considerably smaller than the right. The respiratory motion here, as in the amphibia, is unassisted by a diaphragm, and is principally effected by the ribs and abdominal muscles.

In *Saurian* reptiles the respiratory organs are generally formed pretty nearly as in tortoises. The larynx is tolerably simple, without vocal ligaments, and in the chameleon is furnished with a small sac-shaped appendage: in most Saurians, *e.g.* the crocodile, it opens by a longitudinal fissure; but in the chameleon by a transverse one. This opening is always unconnected, being placed far back, and somewhat covered by the posterior edge of the tongue in the crocodile, but in other species lying more forwards. Many of the species belonging to this order have the power of emitting a sound by the voluntary tension of the rima glottidis, as is known to be particularly the case in the Geckos, where the tongue, which can be thrown back like that of the frog, appears to serve as an epiglottis. In the larynx we already find, particularly in the crocodile, a large pointed anterior cartilaginous lamina as a rudiment of the thyroid cartilage. The trachea and bronchi are nearly the same as in tortoises, *i.e.* composed of almost completely circular cartilaginous rings. In the Gecko the trachea is particularly wide and somewhat flattened. The lungs likewise form double cellular sacs, extending downwards far behind the liver; whilst in the crocodile, on the contrary, they remain above the liver, and, consequently, more in the thorax, resembling very nearly, both in their shape and position, the lungs of birds. In the chameleon, the lungs are furnished inferiorly with peculiar finger-shaped appendages. Respiration is effected by the thoracic ribs and their muscles, without the assistance of a diaphragm.

The Circulation of the Blood.—In *Tortoises* the heart is situated immediately above the liver, and close behind the abdominal scutum: it consists of two auricles and a ventricle, the latter being divided into several communicating cells, and presenting a broad circular depression, having likewise strong muscular parietes, and being connected at its inferior obtuse extremity by means of a tendinous ligament to the pericardium, as is the case in many fishes. The auricles are extremely capacious, either of them being very nearly equal in size to the ventricle: they are divided by a septum, which, however, is perforated in the Testudo scorpioides. The right receives the blood of the body by means of the venæ cavæ, whilst the oxygenized blood from the pulmonary veins enters the left by a fissure-like valvular orifice. The internal arrangement of the ventricle varies somewhat in different instances; in some, *e. g.* the Testudo græca, it is little more than a simple cavity, rendered irregular by the projecting bundles of fibres of its parietes; in others, on the contrary, *e. g.*, the T. imbricata, these fibres are so very prominent, and appear to divide the cavity so completely into several cells, that Mery was induced to admit the existence of a ventricle for the pulmonary artery and aorta, in addition to a right and left ventricle. Whether the cavity, however, be simple or complicated, the course of the blood through the heart is always such, that the pulmonary blood enters at the left side, is mixed with the blood of the venæ cavæ rather towards the back part of the heart, and then passes on the right side into the aorta, and anteriorly into the pulmonary arteries.

Fig. 221.

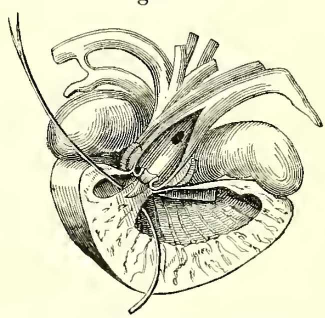


Heart of the Tortoise. (*After Bojanus.*)

The ventricle opened in front, the left aorta laid open, and a bristle placed in the pulmonary artery.

The principal arterial trunks form a circle round the œsophagus, which we must consider as a repetition of the branchial arteries. The aorta, which in the T. imbricata is furnished with two semilunar valves, arises double from

Fig. 222.



Heart of the Tortoise. (*After Bojanus.*)

The ventricle laid open in front, the pulmonary artery slit up, a bristle placed behind a columna carnea, which forms an imperfect septum.

the right side of the heart, a branch ascending from the division to form the axillary and carotid arteries; whilst the two great lateral trunks bend outwards right and left; the left, after giving off some branches to the intestinal canal and liver, unites on the vertebral column with the right and larger branch, forming with it the descending aorta which supplies the other parts of the body, a vascular circle being thus produced precisely as in the frog. A second circle, as has been proved by the observations of Meckel and Munniks, is formed by the pulmonary artery, which, like the aorta, is furnished with two semilunar valves, and immediately after its origin divides into a right and left branch, each of which enters one of the lungs; but, at the same time, communicates with the corresponding branch of the aorta by means of an arterial canal (ductus Botalli), which, probably, is permanently pervious. As a consequence of these dispositions, but a small part of the blood is exposed to the action of the atmosphere, and the oxidation of the blood would be even less perfect than in fishes, where all the blood passes through the gills; were it not that in the latter the respiration is merely of water, and that probably in these and other amphibia there is, in addition to the pulmonary respiration, a respiration of an aqueous kind performed by the permanently existing allantois. As to the veins, it is remarkable that here, according to the investigations of Bojanus, the blood of the whole posterior part of the body, the abdominal coverings, posterior extremities, &c. (with the exception of the venous trunk belonging to the kidneys and sexual organs), is carried into the liver by two trunks, in order to circulate partly in this organ, and partly, according to Jacobson, by means of inferior renal veins in the kidneys, previous to arriving at the heart. The venous blood of the body, as well as that of the lungs, is collected into a venous receptacle for each, close to the auricles, which it then enters in the manner already described.

In *serpents*, the heart is situated towards the middle line of the body, in front of the lungs, and above the liver. Here, also, it is furnished with a left pulmonary auricle, and a right systemic one, which is nearly as large again as the former; both open into the simple and fleshy oblong ventricle, from which arises a double aorta, the branches of which meet again on the vertebral column. The pulmonary artery is single in those serpents where the lung is single.

In *lizards*, the structure of the heart offers a great similarity to that of tortoises, consisting of two separate auricles, and a single ventricle, which, however, is generally divided into several cells. In several species, *e. g.* the crocodile, the heart is attached by a tendinous ligament to the pericardium. The situation of the heart is here again usually immediately above the liver; though, according to Cuvier, in the iguana, at a considerable distance from it, and quite in the front part of the thorax. Its auricles are proportionately smaller than in tortoises, and separated by a thin septum, which is perforated in the *Lacerta apoda*. The ventricle, the form of which is tolerably similar to those of the human heart, is divided, in the crocodile, into three anastomosing cells, in such a manner that the blood of the venæ cavæ passes from the right auricle into the two inferior cells on the right side, from which the pulmonary artery and left ascending aorta arise; whilst, on the contrary, the pulmonary venous blood flows from the left auricle into the left superior cell, which is more distinct from the other two, and which gives origin to the right aortal, carotid, and axillary trunks: the latter vessels, consequently, are not only filled by blood that is more oxidised than that of the left aorta, but also contains a smaller proportion of venous blood than the arteries of the tortoise, inasmuch as but little blood penetrates this from the other two cells.

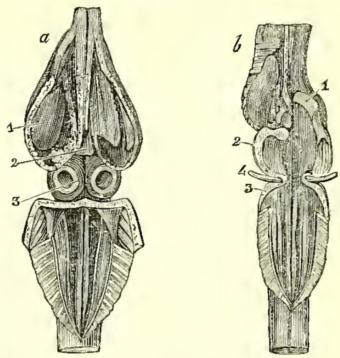
According to Mr. N. M. Hentz, the American alligator (*Crocodilus lucius*) presents a much more perfect structure of the heart than any other of the reptilia, the two ventricles not having any immediate communication. From his description the following particulars are derived. The vena cava superior follows the course of the right subclavian artery in its passage through the chest, and descends to the pericardium to join the vena cava inferior opposite the right auricle. In its course upwards, the inferior cava runs upon the right side of the spine until it reaches a straight channel in the substance and near the edge of the liver, where it receives four or five venæ cavæ hepaticæ. A vein analogous to the right subclavian enters the upper part of the right auricle at its left side. The auriculo-ventricular opening of the right heart is furnished with two valves. The right ventricle opens into two arterial tubes, of which one is the pulmonary artery; the other, at the left and upper part of the ventricle, is furnished at its base with two semilunar valves, and terminates in the left aorta. There is not any direct communication between the cavities of the two ventricles. The left ventricle, which is rather smaller than the right, and situated behind and somewhat above it, has also two valves at the orifice by which it communicates with the auricle. Like the right ventricle, also, it opens into two arterial tubes, of which the first leads into the left aorta, and is separated from the corresponding orifice of the right ventricle by a cartilaginous septum only. It is important to observe that this septum interrupts the immediate communication between the cavities of the two ventricles (for they communicate intermediately by means of the artery from each opening into the left aorta), and constitutes the most essential variation of the structure of the heart in this, from what is found in other Saurians. This first branch, arising from the left ventricle, is bordered by a valve at its origin that nearly closes its cavity. The second artery from the left heart divides

shortly after its origin into three branches, of which one is the right or systemic aorta, the second the right subclavian, and the third the common trunk of the carotid and left subclavian arteries. The left or splanchanic aorta, previous to dividing among the viscera, gives off a large branch which communicates with the right descending or systemic aorta. The three great arteries, viz. the pulmonary, and right and left aorta, are closely connected together immediately after their origin, and dilate into expansions which are collectively larger than the cavities of the heart. In the common state of circulation the blood passes from the right ventricle chiefly into the pulmonary artery, and partly, also, into the branch arising from it, to enter into the left aorta. The blood of the left ventricle, on the other hand, is thrown into the right aorta, right subclavian, and carotid arteries, a small quantity only passing into the left aorta. When the animal is under water, the action of the lungs being interrupted, and the circulation of blood through them suspended, a larger proportion of the contents of the right ventricle must pass into the branch of communication with the left aorta, and it is probable that under such circumstances only does it happen that the blood sent to the various organs is an admixture of arterial and venous blood, as in the Chelonia and other Sauria.

In the serpent (*Python Tigris, Dauel.*) the blood of the general system is collected into a large elongated sinus, formed by the union of the inferior with the right superior cava. The left superior cava winds round the back of the left auricle, receives the coronary veins, and terminates in the lower part of the orifice which leads from the above sinus to the right auricle. This orifice is protected by two elongated semilunar valves. The whole of the inner surface of the auricle, with the exception of these valves and the opposite valve of the foramen ovale, is reticulated with delicate muscular fasciculi. The left auricle receives the blood from the lungs by a single pulmonary vein, and has a similar muscular structure: there is no valve at the termination of the vein in this auricle. The blood enters the posterior or aortic division of the ventricle by two crescentic apertures, which are each provided with a single semilunar valve, extended from either side of the septum of the auricle. The fleshy septum, which extends from the base of the ventricle to the space between the roots of the pulmonary and systematic arteries is incomplete at its upper and anterior part, and leaves there a free communication between the pulmonary and aortic chambers: these also intercommunicate by several round apertures of different sizes near the apex of the ventricle, which serve to thoroughly blend together the two kinds of blood, before they are expelled, thus mixed, along the three arteries which separately arise from the ventricles. The origins of the pulmonary artery and left aorta are each provided with a pair of semilunar valves. The carotid arteries are given off from the right aorta, which afterwards unites with the left aorta at some distance below the heart.

Nervous System. — The brain of reptiles, in

Fig. 223.



Anatomy of the Brain of Turtle. (*After Swan.*)

a. 1, corpus striatum and a lesser oblong eminence seen on opening the lateral ventricle; on the left side the choroid plexus is seen passing through an opening in the septum, to communicate with that of the right side; part of the striated body has been removed on the right side; 2, thalamus of the optic nerve; 3, optic lobe and ventricle continued forward under the thalami, forming a resemblance of the third ventricle, and then backwards into the cerebellum, and to the calamus scriptorius.

b. 1, cut surface, from which the striated body has been removed; it is the crus of the brain, and is somewhat connected with the commissure of the optic nerves: the thalamus on this side has been cut off at its connection with the optic tract. 2, Optic lobe, from which more has been removed than in the preceding figure. 3, Cerebellum, from which more has been removed than in *a*; two longitudinal bands are continued on from the base of the optic lobes, and terminate near the calamus scriptorius, by being implanted into the anterior portion of the oblong medulla: on each side of these, others less distinct may be observed. 4, fourth nerve.

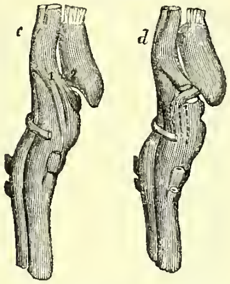
the completeness of its structure, occupies a position intermediate between that of birds and fishes; it resembles the former in the smoothness of its surface and the small size of the optic thalami, and the latter in the length of the olfactory lobes, and their continuity with the anterior extremity of the hemisphere; its proportionate size relative to the dimensions of the body is, however, far inferior to that of birds, although it still completely fills the cranial cavity.

The olfactory lobe of the brain is hollow, and its cavity communicates with the ventricle contained in the cerebral hemisphere. Each hemisphere, as in birds, consists of a central portion, or corpus striatum, the relative size of which varies in different orders, and of a nervous expansion which incloses the ventricle above and on its inner side.

The optic thalami are small, and occupy their usual position on each side of the third ventricle. The tubercula quadrigemina are situated as ordinarily above the aqueduct: they are of a rounded form, and, as in birds, contain a ventricular cavity, which is in communication with the third ventricle. The anterior and posterior commissures of the

brain occupy their usual position, but there is no commissura mollis. The cerebellum is generally extremely small, and in some cases is even reduced to a simple transverse lamella, which does not entirely cover the fourth ventricle, formed as usual by the separation of the posterior columns of the

Fig. 224.



c, lateral view of the brain of a turtle; 1, optic tract; 2, crus cerebri.

d, the same: a portion of the optic nerve has been removed to show the crus cerebri passing upwards. (*After Swan.*)

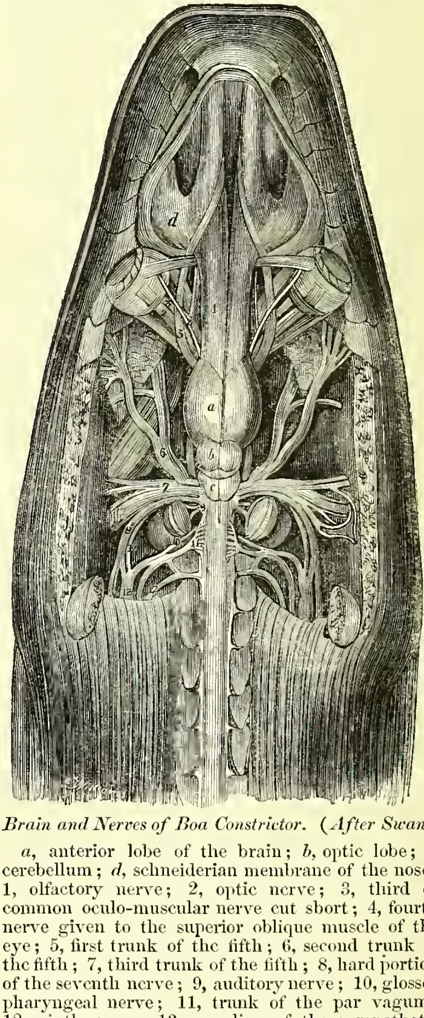
spinal chord. The inferior surface of the brain is almost smooth, presenting no other elevations than those formed by the union of the optic nerves and by the tuber cinereum. As there are no lateral lobes to the cerebellum, of course no traces of a pons varolii exist. As in birds, a vascular inflation, which seems to represent the fissure of Sylvius, separates each hemisphere into two lobes, into the posterior of which the lateral ventricle penetrates. The pineal and pituitary bodies are met with in all reptiles.

In the *Chelonian* reptiles the cerebral hemispheres contain as usual a ventricle, in which may be perceived a body analogous to the corpus striatum, presenting an arrangement very similar to what is observed in birds, only it is much less voluminous, so as to occupy a small portion comparatively of the interior of the ventricle. The crura cerebri, when they reach the lobes of the hemispheres, do not, as in mammalia and in birds, immediately dilate into large ganglia, but curving upwards and backwards, expand on each side into a tubercle, which is the corpus striatum. The optic thalami are very small, but the pineal gland which lies upon them is of considerable bulk.

The bigeminal tubercles are of a rounded form, and instead of being separated from each other by a slight groove, as in the mammalia, a deep fissure is interposed between them which penetrates to the roof of the aqueduct, and contains a fold derived from the pia mater.

The cerebellum is nearly hemispherical in its form, consisting of an arched layer of nervous substance of equal thickness throughout, which spreads over a portion of the fourth ventricle. The remainder of that cavity is covered by a vascular plexus, derived from the sides of the medulla oblongata, which forms a sort of valve, and by becoming united to the margin of the cerebellum, completes the roof of the fourth ventricle, which is large and prolonged very far back. The anterior columns of the spinal chord form a very distinct projection into the floor of this ventricle, as they advance upwards towards the brain. A similar disposition exists in the crocodiles, and in the *Saurian* reptiles generally; the principal differences being that the hemispheres are proportionally larger, and do not separate from each other so as to display the optic thalami; the olfactory bulbs also are less closely approximated to the cerebral hemispheres, with which they are sometimes connected by the intervention of a narrow pedicle, in which, however, a canal is always to be detected, communicating between the ventricles and the cavity of the bulb. The corpus striatum is comparatively larger than in the Chelonians, occupying a considerable proportion of the base of the

Fig. 225.



Brain and Nerves of Boa Constrictor. (*After Swan.*)

a, anterior lobe of the brain; *b*, optic lobe; *c*, cerebellum; *d*, schneiderian membrane of the nose; 1, olfactory nerve; 2, optic nerve; 3, third or common oculo-muscular nerve cut short; 4, fourth nerve given to the superior oblique muscle of the eye; 5, first trunk of the fifth; 6, second trunk of the fifth; 7, third trunk of the fifth; 8, hard portion of the seventh nerve; 9, auditory nerve; 10, glosso-pharyngeal nerve; 11, trunk of the par vagum; 12, ninth nerve; 13, ganglion of the sympathetic nerve, as in *fig.* 226; 14, a branch of the sympathetic nerve passing to the palatine nerve, as in *fig.* 226.

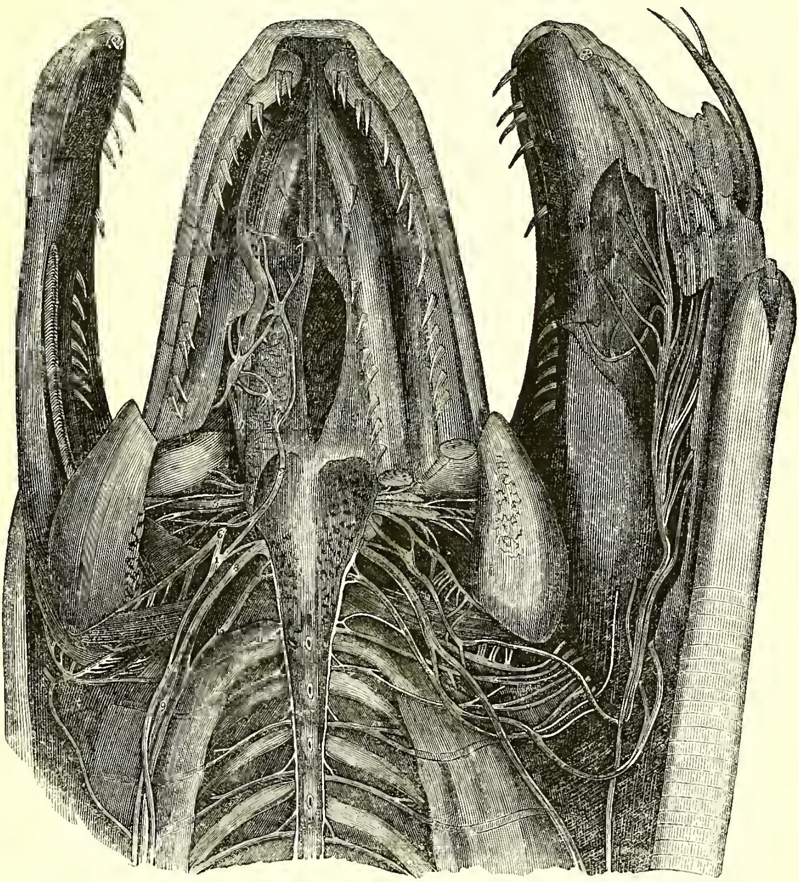
hemisphere, and projecting considerably into the lateral ventricle. The furrow which separates the bigeminal bodies is not so deep in the Saurians as in the Chelonian order. The cerebellum is very small, being represented by a transverse layer of nervous substance. In the *Ophidian* reptiles the two hemispheres form together a mass which is broader than it is long; the olfactory bulb is frequently of very large size, as, for example, in the Python (*fig.* 225); the corpus striatum is much smaller than in the Saurians. In the Python it is divided. The bigeminal tubercles are almost globular in many species, and much smaller than the hemispheres behind which they are situated. In the Python they are remarkable, inasmuch that they are four in number, and closely resemble the corpora quadrigemina of mammalia.

The cerebellum of serpents (*fig.* 225, *c.*) is exceedingly small and flattened; it has the shape either of the segment of a circle or of a thin quadrilateral lamina, which partially covers the fourth ventricle.

In reptiles, as in birds, the medulla spinalis is permeated by a canal, which is lined internally with grey substance. In the Saurian and Ophidian reptiles this canal extends as far as the first coccygeal, but in the Chelonians it is shorter.

The origin of the nerves derived from the encephalon and spinal chord closely resembles what is met with in the higher vertebrata: their general distribution will be best understood by referring to the explanations appended to the annexed figures, copied from Mr. Swan's elaborate work on the Comparative Anatomy of the Nervous System.

Fig. 226.



Nerves of Boa Constrictor. (*After Swan.*)

1, ganglion of the sympathetic nerve, situated near to, and connected with, the trunk of the par vagum. 2, a branch of the sympathetic nerve passing some way in a canal at the base of the cranium, and forming a small ganglion with a branch of the second trunk of the fifth; it sends filaments to the membrane covering the posterior part of the mouth and palate, one of which communicates again with the second trunk of the fifth before its termination; the ganglion then sends another branch forward to form another glanglionic union with a branch of the second trunk of the fifth, and from this a branch is sent to the posterior part of the nose to ramify on the schneiderian membrane; other branches are given to the membrane covering the mouth and palate, and one passes forward and communicates again with a branch of the second trunk of the fifth, and is distributed on the membrane covering the anterior part of the mouth

and palate. It is worthy of remark, that the nerves distributed on the membrane of the mouth and nose communicate so many times with branches of the second trunk of the fifth, and their connexion is so much greater than in the turtle; but in this creature the palate is horny, and not so extensive in proportion to the size of the head. 3, prolongation of the sympathetic connected with the trunk of the par vagum, but not directly with the ganglion of the sympathetic; it communicates with the ninth nerve, then passes down the spine and communicates with the eleven superior spinal nerves; it emerges on each side at the place the superior branches of the vertebral artery enter to distribute branches in the intercostal spaces; it is continued downwards in a very fine plexiform prolongation with the vertebral artery, as far as the origin from the right aorta; it then branches to each side beneath the membrane connecting the viscera with the ribs and spine, and communicates with filaments of the par vagum; it is afterwards continued downwards, receiving a filament from each spinal nerve; in its course it is a very fine nerve, and has not any more ganglia than the first, and those communicating with the second trunk of the fifth; but at different points from which the nerves pass to the viscera, there is an appearance of a delicate plexus: this plexiform structure varies in different parts, and becomes much greater about the beginning of the intestine, where it resembles that corresponding with the semilunar ganglion in the turtle; near the kidney it assumes the form of a nervous membrane or retina, before it is distributed on the urinary and generative organs. Branches pass from the plexuses with the arteries to the different viscera. 4, second trunk of the fifth; after communicating with the sympathetic, and giving filaments to the membrane of the mouth, palate, and nose, it passes out of its canal in the upper jaw, and terminates in branches on the upper lip. 5, third trunk of the fifth; it gives branches to the muscles of the jaws, the greatest portion of it then passes within a canal in the lower jaw; it sends three branches through the opening at the inferior margin of this part, two of them to communicate with the branches of the par vagum and ninth, distributed on the muscles and parts underneath the jaw; the other to give filaments to the membrane of the mouth as far as the sheath of the tongue: the trunk is continued onwards through the foramen, near the chin, to divide into branches and terminate on the lower lip. 6, hard portion of the seventh; it communicates with the ganglion of the sympathetic, and then passes through the digastric muscle, to which it gives a branch; it communicates with the first spinal nerve, and terminates on the costomaxillary muscle. 7, glosso-pharyngeal nerve; it passes to the ganglion of the sympathetic. 8, trunk of the par vagum; it communicates with the sympathetic, and then with a branch that appears to be the continuation of the glosso-pharyngeal from the ganglion of the sympathetic; it sends a branch to communicate with the ninth, to pass to the muscles, &c., of the fauces; and is then continued downwards close to the trachea, in company with each jugular vein; on the left side it also accompanies the carotid artery, and from this a small vessel also ascends with the right trunk; it sends filaments on the large vessels towards the heart, and others behind each aorta, similar to the recurrent nerves, to be distributed on the trachea and œsophagus; each trunk, for a short space, accompanies its corresponding pulmonary artery: a little above the liver it passes in front of the superior part of the lungs, and proceeds a short distance, where it is joined by its fellow to form a single nerve; this is continued downwards under a thick membrane on the liver, and appears to give filaments to this viscus, the lungs, and œsophagus: about the termination of the liver it sends a large branch, which has communicated freely with branches of the sympathetic to the left surface of the stomach; this gives filaments to the lowest part of the lungs, and terminates on the stomach. The right division, or the continuation of the nerve itself, having communicated several times with the left division and filaments from the plexus of the sympathetic, is continued a short way on the membrane connecting the viscera, it passes on the right surface of the stomach, distributing branches to this viscus, and terminates on the beginning of the intestine, reaching as far as the pancreas. 9, a nerve from the ganglion of the sympathetic; it appears to be the continuation of the glosso-pharyngeal after its junction with the ganglion, it communicates with the ninth after its connection with a branch of the trunk of the par vagum, and terminates on the glottis and muscles attached to the anterior point of the jaw for drawing forward the trachea. 10, ninth nerve; it receives a branch from the trunk of the par vagum, and from the hard portion of the seventh; after this has communicated with the first cervical nerves, it gives off several branches to the muscles of the tongue and throat, and one that reaches to the end of the tongue, and one to communicate with branches of the third trunk of the fifth, issuing out of the inferior part of the lower jaw. The glosso-pharyngeal, the trunk of the par vagum, and the ninth, are so connected together that it is difficult to determine precisely to which nerve each branch belongs; they have been with great care apportioned to their respective nerves in this description.

Sympathetic System.—The sympathetic system of the tortoise is so feebly developed as to be detected with difficulty, except in the interior of the carapax, where nervous ganglia are distinctly recognisable both in the peritoneal folds and on the bodies of the vertebræ.

The ganglia exactly resemble those of birds; they give off two filaments superiorly and two inferiorly: the latter pass beneath the transverse process of the vertebræ, which is here connected with the carapax. From the inner margin of each ganglion a splanchnic nerve is given off, which runs to assist in forming a plexus, ramifications from which accompany each of the arteries given off by the aorta, and likewise assist in forming a pulmonary plexus. The intercostal ganglia may be traced as far as the sides of the first vertebra of the tail.

Bojanus has represented the sympathetic of the European tortoise (*Emys europæa*) as accompanying the carotid artery into the cranium, and uniting with the vidian and the facial nerves. On issuing from the cranium, he describes it as being closely connected with the vagus and with the glosso-pharyngeal nerves, so that it is difficult to say whether a superior cervical ganglion exists or not; and as the cervical vertebra are here devoid of the vertebral canal, the nerve is equally inseparably connected with the vagus throughout the whole length of the neck. Below the sixth cervical vertebra the sympathetic nerve separates itself from the sheath of the vagus, and becomes connected with a middle cervical ganglion, whence issue filaments that are distributed to the aorta, the cardiac plexus, and the cæliac plexus. Between the seventh and eighth cervical vertebræ is situated the inferior cervical ganglion, which seems to be merely an elongated swelling of the nerve;

subsequently two dorsal ganglia occur, and further down, towards the middle of the back, there occurs a third and last ganglion, which furnishes the splanchnic nerve: the remainder of the sympathetic is made up of one or two cords, which, in the sacral region, give off a great number of branches, the divisions of which form the renal, hypogastric, and sacral plexuses.

According to Mr. Swan, in the turtle (*Testudo Mydas*), the sympathetic is free and distinct throughout the whole length of the neck, but it gives off filaments of intercommunication to the nervus vagus. One of its branches passes along with the division of the carotid artery into a canal in the base of the cranium, gives off a filament to the facial, and communicates with the second division of the fifth pair.

Organ of Hearing.— In all reptiles the organ of hearing is constructed to appreciate sounds communicated through the medium of the atmosphere, and consequently differs from that of fishes in several important particulars, amongst the most obvious of which is the addition of a membrana tympani and tympanic cavity, wherein is lodged an ossiculum auditus, the office of which is to convey the vibrations of the tympanic membrane to the labyrinth contained within the skull.

In all reptiles the internal ear consists of the same parts as that of fishes, only they are comparatively of smaller size and more compact in their arrangement. In crocodiles and lizards, the internal ear consists of three semicircular canals, which exhibit the usual arrangement, each canal forming a considerable portion of a circle, and presenting internally a membranous ampulla before opening into the vestibule.

Towards the interior of the skull, there is an organ appended to the vestibule, which is evidently analogous to the *sac* met with in the ear of fishes. The walls of this sac are membranous, and copiously supplied with bloodvessels. It is found to contain in its interior three otolithes; but these are very small, and even of softer texture than those of the chondropteriginous fishes.

Besides the above parts, the internal ear of reptiles presents for the first time an additional part, which is undoubtedly a rudimentary *cochlea*. This is an appendage to the vestibule, of a conical shape, and slightly bent towards its extremity; it lies inferior to the vestibule, its apex being directed towards the mesial line of the cranium. On opening this organ, it is found to be divided internally into two compartments by a double cartilaginous septum: the two compartments communicate with each other towards the apex of the cone, whilst at their opposite extremities one of them is found to open into the vestibule, whilst the other terminates at a small orifice closed by membrane, which communicates with the tympanic cavity. This organ, it will be perceived, is precisely comparable to the rudimentary cochlea met with in the ear of birds, the two canals representing respectively the scala vestibuli and the scala tympani of the human ear. In *Crocodiles* this cochlea is of considerable size, and may be easily exhibited in very young individuals; it is more difficult to find in the *Chameleon* and in *Lizards*, whilst in *Serpents* it is reduced to a very rudimentary condition. In *Tortoises*, that part of the ear which seems to represent the rudimentary cochlea resembles exactly that part of the ear called by Cuvier the *sac*, both in its shape, and from the circumstance of its containing otolithes, and he is disposed to consider this sac as truly analogous to the cochlea of the human ear; whilst that portion of it which he calls the sinus, he considers as representing the vestibule.

In all reptiles the membranous *labyrinth* is enclosed in an osseous sheath, which embraces it more or less closely in different genera; in the Saurians the bony labyrinth is complete, but in Tortoises that portion which separates the vestibule from the cranial cavity is not ossified, but remains partially membranous.

The tympanic cavity, which in reptiles is for the first time interposed between the vestibule and the exterior of the body, varies in its arrangement in different genera. In the *Crocodiles* this cavity might be divided into two portions, one external, which is very wide, and is closed externally by the membrana tympani and the skin; and an internal portion, which is separated from the former by a constriction. It is in this latter compartment that the two fenestræ are situated; and it contains, moreover, some cavities which are analogous to the mastoid cells, but of much larger size than in mammiferous animals. The position of the tympanum in this reptile is near the upper part of the cranium.

The tympanic cavity of the *Chelonian* reptiles is situated much more laterally than in the crocodile, and the constriction which separates the external from the internal portion is less remarkable. The internal compartment of the tympanum is here prolonged backwards into a wide rounded cell. At the bottom of this cavity, just opposite the membrana tympani, there is a narrow canal leading to the fenestra ovalis, in which the ossiculum auditus is lodged. The Eustachian tube is a canal of moderate length, which runs downwards and slightly backwards to communicate with the palate just behind and internal to the articulation of the lower jaw.

In the generality of *Saurian* reptiles, the walls of the tympanic cavity are membranous posteriorly and inferiorly: the Eustachian canal is very short, and opens into the palate. In many genera the tympanic bone is much enlarged superiorly, so that the cavity of the tympanum is made more extensive: this arrangement is most conspicuously seen in the genus *Draco*.

In *Serpents* there cannot, strictly speaking, be said to be any tympanic cavity, the handle of the auditory ossicle being imbedded amongst the flesh, so that its extremity only touches the skin close behind the articulation of the lower jaw.

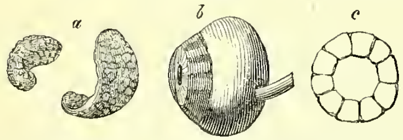
In all reptiles there is but one ossiculum auditus (*the columnella*), which is generally of a trumpet shape. Its external extremity is in the Saurians connected to the membrana tympani by means of a cartilaginous process; but in tortoises it is implanted directly into the membrana tympani, which has a cartilaginous texture. The inner extremity of the auditory ossicle enlarges into an oval or triangular disc (*Patina*), which is applied to the fenestra rotunda, in the same way as the disc of the stapes is in the ears of mammalia.

It does not appear that there are any muscles implanted into the auditory ossicle of the reptilia. In most reptiles that possess a membrana tympani, it is situated on a level with the general integument. In the crocodile, however, something like an external meatus exists.

Organ of Vision.—In all the reptilia the eye resembles, in its general structure, that of birds and quadrupeds: there are, however, certain modifications rendered necessary by the habits of these animals, many of which are semi-aquatic in their habits, which it will be important to notice.

The sclerotic coat of the eye is very similar

Fig. 227.



a, lachrymal gland of a tortoise; *b*, eye-ball of a tortoise; *c*, circle of osseous sclerotic plates. (*After Bojanus.*)

in its composition to the sclerotic of a bird; and in like manner, in many reptiles, contains in its anterior portion a circle of horny plates, which are enclosed between its laminæ without being continuous with the substance of the membrane, from which they are consequently easily detached. These plates are generally ten or twelve in number, and are constantly met with in tortoises, and also in the crocodiles, chameleons, and many other lizards. In many genera the sclerotic is divided into two layers, the external being fibrous and of equal thickness throughout its whole extent; whilst the internal layer is of a cartilaginous texture, and is thicker at the posterior part of the eye than it is in front. This layer in the vicinity of the entrance of the optic nerve is perforated by numerous foramina for the passage of bloodvessels.

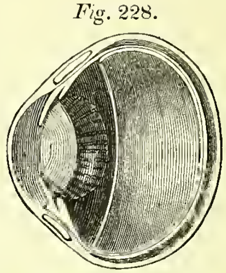
The structure of the cornea presents nothing remarkable, but its convexity varies considerably in different genera.

The choroid coat of the eye exhibits the usual structure. In lizards and serpents the ciliary processes are scarcely distinguishable; and in the Chelonians their existence would be doubtful were it not for the elegant impression left by them upon the vitreous humour. In the crocodile, however, these processes are well developed, and very beautiful.

The iris, to some extent, resembles that of fishes, having frequently the same metallic splendour. The shape of the pupil varies: in the crocodile it is a vertical slit, like that of the cat; in the tortoise it is round, as likewise in the chameleon and the generality of lizards.

The optic nerve enters the eye externally

Fig. 228.



Section of the Eye-ball of a Tortoise. (*After Bojanus.*)

to the axis of vision, piercing the membranes of the eye, as in the mammiferous classes: arrived in the interior of the organ, it forms a small tubercle, from the circumference of which the retina takes its origin.

In many reptiles the falciform ligament usually met with in the eyes of fishes is still perceptible; and in some genera, such as the lizards, the iguana, and the monitor, there is a cylindrical membranous process covered with black pigment, which passes from the insertion of the optic nerve to the capsule of the crystalline lens, and which is evidently the representative of the pecten common to the eyes of birds.

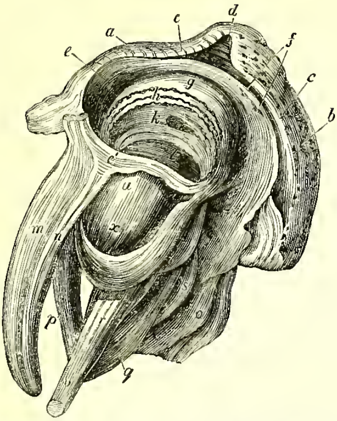
The aqueous and vitreous humours offer no peculiarity worthy of notice; and the same may be said of the crystalline lens, which, however, differs in the convexity of its facets in different genera.

Appendages to the Eye.—The eye of reptiles is moved by the six ordinary muscles, which are disposed as in fishes; but besides these, there are four smaller muscles representing the suspensory or choroid muscle of quadrupeds: these latter closely embrace the optic nerve, and spread over the convex portion of the sclerotic.

In the *Chelonian* and *Saurian* reptiles the upper and lower eyelids are completely developed, and accurately close the conjunctival cavity. There is also a well-developed *nictitating membrane*, or third eyelid, which is situated vertically at the inner canthus of the eye, and has a horizontal motion over the cornea. In the crocodiles the nictitating membrane is moved by a special muscular apparatus; its muscle, the nictitator, arises from the inner and upper part of the eye-ball, and running outwards and downwards winds round the optic nerve, and the suspensory muscles of the eye (which latter serve to protect the nerve from the pressure of the nictitator muscle), and is inserted into the inferior angle of the nictitating membrane, which it thus draws

outwards over the eye-ball, while at the same time it rotates the eye-ball inwards beneath the membrane, the muscle being attached to move-

Fig. 229.



An external View of the Eye, Eyelids, Muscles, &c. of a Crocodile. (After John Hunter.)

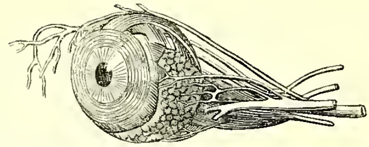
a, the external surface of the upper eyelid; *b*, the external surface of the under eyelid; *c*, points to the edge of both eyelids; *d*, the inner angle or canthus of both eyelids; *e e*, the internal surface of the eyelids covered by the tunica conjunctiva; *f*, point, to the two puncta lachrymalia on the inside of the under eyelid; *g*, the external surface of the third eyelid, or membrana nictitans; *h*, the loose or free edge of the same; *k*, the opening of the duct of the lachrymal gland (glandula Harderii) upon the inner surface of the nictitating membrane; this surface has been raised from the cornea, to which it naturally lies contiguous; *l*, the muscle which expands the membrana nictitans, and draws it over the ball of the eye. This is the only muscle which is subservient to the movements of the nictitating membrane; it is analogous to the pyramidalis of birds, the quadratus muscles and its sheath being wanting in reptiles; *m*, the levator muscle of the upper eyelid; *n*, the portion of the above muscle lost in the tunica conjunctiva; *o*, the depressor muscle of the under eyelid; *p*, the rectus superior, or attollens oculi; *q*, the rectus inferior, or deprimens oculi; *r*, the rectus externus, or abducens oculi; *s*, the obliquus inferior: only a small portion of it is here seen; *t*, the cornea; *u u*, the globe of the eye behind the cornea; *v*, the optic nerve; *x*, insertion of the choroid muscle, which consists of four distinct portions surrounding the optic nerve.

able points at both extremities. The quadratus muscle, which in birds forms a loop for the passage of the tendon of the nictitator, does not exist in the reptilia. There is a gland especially appropriated to facilitate the movements of the nictitating membrane by its secretion, which escapes through a duct opening upon its inner surface. This gland is analogous to the Harderian gland of quadrupeds.

The lachrymal gland is generally of large size, and consists of a thick broad conglomerate mass, which surrounds the upper and outer portion of the eye-ball: its duct is short and wide, and terminates just above the external canthus of the eye.

In the annexed drawing, copied from one in the Hunterian collection, the eye, eyelids, and muscles of the eye-ball of the crocodile are represented.

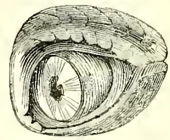
Fig. 230.



Eye-ball of Tortoise: shewing the lachrymal Gland in situ. (After Bojanus.)

The common *Lizards* have, for eyelids, a kind of circular veil, extended before the

Fig. 231.



Eyelids of Tortoise. (After Bojanus.)

orbit, and perforated by a horizontal fissure, which is capable of being closed by a *sphincter* muscle, and opened by a levator and depressor: its inferior part has a smooth round cartilaginous disc, as in birds. There is, besides, a small internal eyelid, but it has no proper muscle; it is entirely wanting in the chameleon, in which animal, also, the slit of the eyelids is so small that the pupil can scarcely be observed through it. The Gecko has no moveable eyelid: its eye is protected by a slight margin of the skin, as in serpents. A similar disposition appears in the Scink.

The horizontal eyelids of the reptilia close exactly; they are generally slightly enlarged at their margins, but are never furnished with ciliæ.

The eye of *Serpents* is protected by an eyelid of a very remarkable character; for that it is an eyelid, and not, as is very generally supposed, the cornea, its anatomical relations abundantly prove. It consists of a transparent membranous expansion, which is immoveably fixed in a kind of frame formed for its reception by a circle of scales, usually seven or eight in number, disposed around the margin of the orbit. This eyelid is formed of three superposed layers*: viz., 1st, An epidermic layer, which is elastic and pretty thick where it covers the middle of the eye, but towards the circumference of the eyelid it becomes thinner, and is manifestly continuous with the epidermis that invests the scales in the vicinity of the orbit. This corneous lamella by its solidity is well adapted to defend the eye, and it is this which becomes detached and cast off with the slough of the snake when it moults its skin. 2dly. Beneath this epidermic layer is situated a second

* Vide Cloquet (Jules), Mémoire sur l'Existence et la Disposition des Voies lacrymaux dans les Serpens. 4to, Paris, 1821.

membrane, which is the middle tunic of the eyelid. This is very delicate and soft, and perfectly transparent in the centre, but to-

Fig. 232.

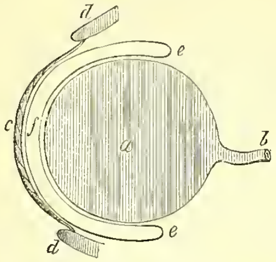


Diagram of the Conjunctiva of a Serpent. (*After Cloquet.*)

a, eye-ball; *b*, optic nerve; *c*, eyelid; *d*, skin; *e e*, *f*, conjunctiva.

wards its circumference it encloses some opaque whitish fibres, supposed by Cloquet to be muscular. This layer, at the margin of the orbit, is manifestly continuous with the dermis: internally it is lined by the third layer, which is mucous, being in fact the membrana conjunctiva, which is reflected on to it from the surface of the eye-ball.

All around the circumference of the eyelid there is a whitish, granular, transparent substance, the nature of which is apparently glandular.

The lachrymal apparatus in serpents consists of a lachrymal gland; of a mucous sac formed by the conjunctiva, into which the secretion of the lachrymal gland is poured; of an excretory duct, or lachrymal canal; and moreover of a large and tortuous cavity, which receives the tears and transmits them into the mouth.

The lachrymal gland is proportionally of very great size, and is situated behind the eye and the post-orbital ligament. By its anterior surface, which is concave, it adheres to the conjunctiva by means of its numerous small excretory ducts. This gland is enclosed in a very delicate cellular capsule. It is made up of rounded whitish granules united together by numerous vessels and nerves.

The conjunctiva lines not only the internal surface of the eyelid, but also a large portion of the cavity of the orbit, from which it is reflected on to the front of the eye-ball, thus forming a complete sac without any opening externally (*fig.* 232, *f*). On the anterior part of the floor of this sac there is a single pore, large enough to admit a hog's bristle. This is the *punctum lachrymale*, which is single like the eyelid, behind and beneath which it is situated: the punctum leads into a very delicate membranous tube, which constitutes the *lachrymal canal*. This latter passes downwards and forwards, enters an infundibular channel in the lachrymal bone, and passing through this, arrives at the external wall of the nasal fossa, with which, however, it does not communicate, but passes on to open into a wide tortuous cavity, named by Cloquet the *intermaxillary sac*.

Urinary Apparatus.—The arrangement of the urinary apparatus is very similar throughout all the oviparous vertebrata. The *kidneys* are invariably situated very far back in the abdominal cavity, where they are suspended beneath the spine. They are distinguished from the same glands in mammalia by the circumstance of their presenting no division into cortical and medullary portions, and by the total absence internally of any pelvis or infundibulum, their whole substance seeming to be made up of convoluted cæcal tubes.

They vary slightly in the different orders in their form and relative size, the principal differences worthy of notice. In Chelonian order they are short, oval masses, of a somewhat prismatic shape, or else, as in the turtle (*Testudo caretta*), they are flat and triangular. Examined superficially, they have the appearance of being divided into numerous lobules, so that their surface has a convoluted appearance, somewhat like that of the human brain; but towards the centre of the organ, this lobulated structure is not distinguishable. They are situated very far back, occupying a very considerable space in the pelvic region.

In the *Saurians* likewise, the kidneys seem externally to be more or less divided into lobules; they are generally almost entirely contained in the cavity of the pelvis, where they are placed side by side beneath the arch of the sacrum, extending backwards even to beneath the tail, so that they are situated immediately above the cloaca. Their shape is also more elongated than in the preceding order.

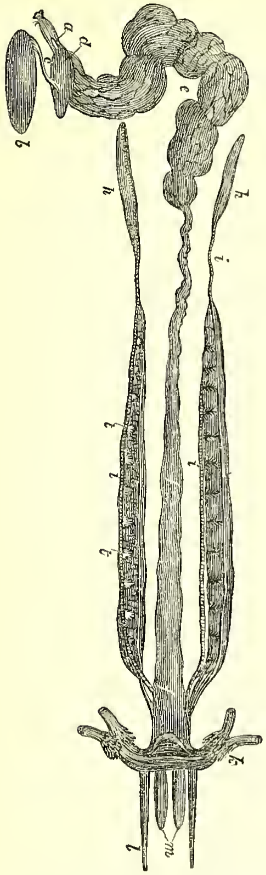
In the *Ophidian* reptiles the kidneys are much elongated, so as to adapt them to the slender shape of the body of the animals; and they are composed of distinct lobes placed one before the other, and connected loosely together, so as not to interfere with the flexibility of the body. For the same reason the two kidneys are not placed upon the same level, but the right is situated considerably farther forward than the left; they are, moreover, only loosely connected with the spine by broad processes of peritoneum, in which they are enveloped; an arrangement which leaves the movements of the spinal column perfectly free.

The kidneys of the reptilia seem to be entirely made up of convoluted uriniferous tubes, which as they issue from the different lobes unite successively to form a common duct, which runs along the external border of the organ, and constitutes the ureter. The common trunks of these urinary canals occupy the fissures between the different lobes of the kidneys, in each of which they divide very regularly as they diverge, so that their ramifications have a pyriform appearance (*fig.* 233, *t t*).

In the embryo and in very young reptiles the kidneys seem to be made up of pyriform vesicles which are arranged transversely, their pedicles terminating at right angles in the ureter; or else they are made of simple tubes disposed in a similar manner. The

arteries of the kidneys penetrate these organs by their inner margin, whilst the trunks of the emulgent veins occupy the opposite border. These latter are two in number, one

Fig. 233.



Generative and Urinary Apparatus of the Rattlesnake (*Crotalus Durissus*).

a, the intestines cut off just below the pylorus; *b*, the gall-bladder; *c*, the biliary duct, that passes through the middle of the spleen,—or, as called by Carus, the pancreas,—and enters the large gut; *d*, the spleen, or pancreas; *e*, the intestines, which were very large and winding, but short; *f f*, the rectum; *h h*, the testes; *i i i*, the vasa deferentia; *k k*, the penis on each side, which first at the root are conjoined, and are thick beset with bristles; *l*, the muscles that serve for drawing in the penis; *m*, the scent-bags; *t t t*, secretory vessels.

of which unites with its fellow from the opposite kidney to form the commencement of the posterior cava. The other communicates with the veins returning the blood from the posterior extremities and the tail; it is this latter vessel which Mr. Jacobson regards as forming the portal vein of the kidneys.*

The *ureters* are longer or shorter in proportion as the kidneys are more or less advanced forwards; they terminate in the cavity of the cloaca, their openings being in the vicinity of the allantoid sac, if that viscus is present. The allantoid sac, generally called by authors the *urinary bladder*, in no case immediately receives the terminations of the ureters, and its presence is by no means constant. In the Chelonian order it is very large, and is divided at its fundus into two portions; but its walls are very thin and membranous. It is likewise met with in the following genera of Saurians; namely, the Iguana, the Tupinambis, Chameleon, Draco, and Stellio; while it is wanting in the Crocodiles, Lizards, Agame, Gecko, and other genera of the same order: it is likewise deficient in all the Ophidians. The fluid contained in this reservoir, when it is present, yields, upon analysis, but very slight traces of urea or uric acid; so that its claims to be considered as being the real urinary secretion have been doubted, although its urinary character has been admitted by Vauquelin and others.

In the Chelonian reptiles the *urine* is a limpid or slightly-coloured fluid; but in the generality of Saurian reptiles (with the exception of the crocodiles), and likewise in all serpents, it is a white soft substance, which hardens on exposure to the atmosphere into a mass resembling chalk. This solid urine is found on analysis to consist almost entirely of uric acid: it contains besides a very small proportion of ammonia of potash and soda in combination with uric acid, and also traces of phosphate of lime and animal matter.

The *Emydes* among the Chelonian reptiles are furnished with two very remarkable accessory bladders, the size of which exceeds that of the urinary bladder itself; but what is very remarkable, these are met with neither in the land-tortoises nor in the turtles. They are likewise deficient in the genus Trionyx. These accessory bladders are of an oval or cylindrical shape, and are so situated, that they can be compressed by the abdominal muscles. Their walls are extremely delicate, and seem to consist only of an external peritoneal coat lined with mucous membrane; no muscular fibres being recognisable in their structure. They are extremely vascular; the blood-vessels forming a rich net-work over their outer surface. Their use is not yet accurately determined, but it seems probable that the tortoises which exhibit this structure are able to fill the accessory bladders with water and perhaps with air, so as to diminish the specific gravity of their bodies. Should this be the case, it will explain why these organs are deficient in the land tortoises, which never enter the water, and also in turtles, which, from their organisation, are well able to swim without such auxiliaries, more especially as the specific gravity of sea-water is much greater than that of fresh. In the Trionyx, also, the extremities form such powerful oars, that additional means of swimming are not required.

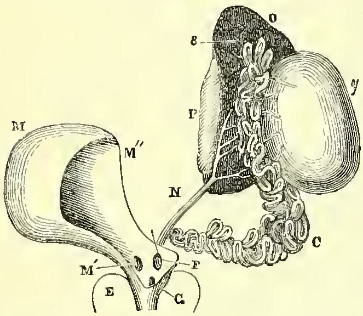
Male Organs of Generation. — In all the three orders of reptiles the general arrangement of the generative system of the males is similar

* *Vide* the article REN.

and conforms very closely to what exists in the class of birds. The *testicles* are invariably two in number, and situated in the abdominal cavity on each side of the spine, their position being more or less advanced forwards according to circumstances: they are, however, constantly in juxtaposition with the kidneys, beneath or in front of which they are always placed. In the Chelonians they are always found to be connected with the inferior surface of the renal glands, which are here situated at the bottom of the abdominal cavity. In the Saurians they are placed in front of the kidneys on each side of the spinal column. They occupy a similar position in the Ophidian order, except that the right testis is in all serpents advanced further forwards than the left.

The intimate structure of the testis is essentially similar in all the reptilia. Each testis

Fig. 234.



Male Organs of Generation, and Kidney of the Tortoise. (*After Bojanus.*)

M, M'', the urinary bladder laid open; O, the left kidney; P, the renal capsule; 8, uriniferous tubes derived from the kidney, which by their union form the ureter; N, ureter; F, common termination of the ureter and of the vas deferens at the neck of the bladder, close to the commencement of the urethral groove; M, ditto of the opposite side; *y*, the testes; C, the vas deferens; E, the bulb of the penis; G, commencement of the urethral groove, just anterior to the openings common to the ureters and the vasa deferentia.

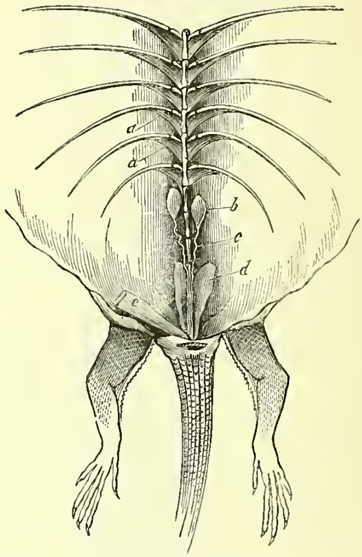
is found to consist of large fascicles of seminiferous tubes, which are connected together by a delicate cellular tissue, and are, generally, easily separable. The seminal ducts derived from all these fascicles unite to form the commencement of the vas deferens, which is very tortuous and folded upon itself, so as to form an *epididymus* situated at the side of the testis. In the Chelonian reptiles the convoluted mass of tube which forms the epididymus is continuous with a very flexuous vas deferens, which is continued as far as the cloaca, into which it opens close to the root of the penis, and in the immediate vicinity of the grooved canal, which, in these animals, represents the urethra.

In Saurians the epididymus forms a detached mass of a pyramidal form, which is longer than the testis itself. The vas deferens derived from it, runs along the external border of the kidney as far as the cloaca, into which it opens.

In Ophidian reptiles the epididymus is proportionally of smaller size, and is in like manner continuous with a flexuous vas deferens, which terminates in the cloaca.

The terminal orifices of the *vasa deferentia* are always situated in the upper wall of the cloaca, external to or above the ureters, and

Fig. 235.



Hinder Part of the abdominal Cavity of Draco volans.

a a, depressor muscles of false ribs; *b*, testes; *c*, vas deferens; *d*, bladder; *e*, rectum.

are disposed in such a manner, that when the penis is double, the orifice of each vas deferens is close to the commencement of the urethral groove of the corresponding penis when in a state of erection. When the penis is single, both the orifices of the vasa deferentia open in the vicinity of the single urethral canal. In some Ophidians the vasa deferentia, near their termination in the cloaca, dilate into a kind of ampulla, which seems to be a reservoir for the reception of the seminal fluid.

The *cloaca* in the reptilia is a wide cavity which receives the terminations of the rectum, of the ureters, of the allantoid bladder, when that viscus is present, and likewise of the vasa deferentia. In the Chelonians and in the crocodiles, which have a single penis, that organ, when in a state of repose, is entirely concealed in the cloacal cavity, the external opening of which is in these genera an oval or longitudinal opening. In the Chelonians the cavity of the cloaca may be divided into two portions: the one anterior, which is of a cylindrical shape, and receives the termination of the rectum, has its mucous membrane gathered into numerous longitudinal folds, and is surrounded with two layers of muscular fasciculi; the external assuming a longitudinal, and the internal a circular arrangement.

This portion of the cloaca is bounded both before and behind by a ring projecting internally, composed of strong muscular fibres, which form two sphincter muscles.

The second portion of the cloaca has its walls thinner than the preceding. The longitudinal folds of the mucous membrane of the first portion suddenly terminate, with the exception of the median fold, which is continued around the termination of the ureter, enclosing it, as it were, between two broad lips, which are then prolonged in the shape of two folds along the median line of the dorsum of the penis, becoming gradually less distinct as the urethral groove which they bound becomes deeper: it is in this second portion of the cloaca that the penis is folded up when in a state of repose.

In the crocodiles the disposition of the cloaca is nearly similar, but in these Saurians there exist on each side of the root of the penis two wide apertures, through which a free communication is established between the exterior and the cavity of the peritoneum.

In the caiman (*Alligator sclerops*) the cloaca is divided into three compartments, the anterior of which receives the rectum; the second contains the orifices of the vasa deferentia, of the ureters, and of the allantoid bladder; whilst the third is appropriated to the lodgment of the penis. In this case the dorsal groove of the penis is bounded by two folds of mucous membrane, which are prolonged backwards into the middle chamber, so as to establish a communication with the openings of the vasa deferentia.

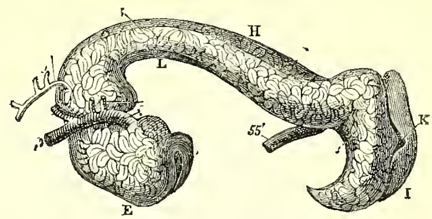
In those reptiles which have the penis doubled, viz. the Saurians (minus the *crocodiles*) and the Ophidians, these organs are not enclosed in the cloaca: in such races the external opening of the cloaca is always a transverse slit, bounded by two lips, the posterior of which is more or less moveable: it is between these lips, just within their lateral commissures, that the two male organs are situated.

The posterior lip of the cloaca encloses in its substance a series of orifices which are the openings of the excretory ducts of as many little glands, which seem to represent the anal glands of other vertebrata: they secrete a thick sebaceous matter.

Besides these, there are in many genera of reptiles a series of crural glands, situated near the orifice of the cloaca; these exist in all the Lacertidæ. In many Iguanidæ and other Saurians these glands become largely developed as the season for impregnation approaches.

In the Chelonian reptiles the *penis* is very large, and both in its structure and form somewhat resembles that of the ostrich. It is long, nearly cylindrical in its shape, and enlarged towards its extremity, which terminates in a point. A deep groove extends along the whole length of its dorsal surface, which becomes gradually deeper as it approaches the glans, near the middle of which it terminates by a kind of orifice, divided into two by a papilla. From the depth of this groove it is evident that the mere approximation of its edges will convert it into a complete canal.

Fig. 236.

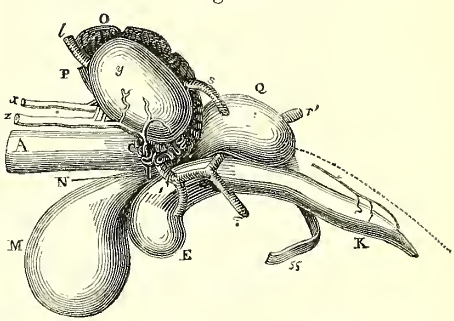


Penis of the Tortoise. (After Bojanus.)

E, bulb; L, corpus cavernosum; H, urethral groove; K, its termination near the centre of the glans; I, glans penis; 55', retractor muscle.

This penis is composed of two corpora cavernosa, the fibrous walls of which are blended together throughout some part of their extent. They commence by two vascular enlargements, analagous to the bulb of the urethra in the penis of mammalia. The erectile tissue is prolonged from this bulb (*fig.* 236),

Fig. 237.



Male Organs of Generation of the Tortoise. (After Bojanus.)

a, the rectum; *c*, convolutions of epididymus terminating in the vas deferens; N, which likewise indicates the point where the urethra enters the cloaca; O, P, the kidney; *y*, the testes; E, the bulb of the urethra; K, cavernous portion; M, the urinary bladder; Q, the left supernumerary lateral bladder; *l*, *r*, *r'*, *s*, *x*, *z*, blood-vessels; 55, retractor muscle of the penis.

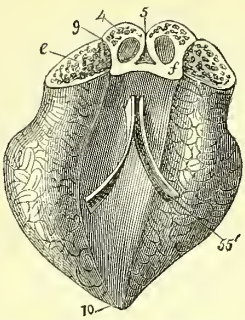
along two canals, the walls of which are fibrous, and at first very thin; but they soon increase in thickness considerably, their cavity becoming diminished in the same proportion. All the enlargement that constitutes glans is composed of this vascular tissue, prolonged from the cavernous body, which is covered by a loose and wrinkled skin, and, moreover, supported by a prolongation of the fibrous wall of the corpus cavernosum, which is continued to its point.

The skin which lines the urethral groove has also a layer of this erectile tissue placed beneath it; but this is equally a prolongation from the erectile tissue contained in the cavernous body.

There is on each side of the dorsal groove

of the penis a canal which at one extremity communicates with the cavity of the peritoneum on each side of the bladder, and by its other end it is prolonged into the substance of the penis as far as the glans, where it terminates in a cul-de-sac, without being perforated by any orifice throughout its whole extent.

Fig. 238.



Section of the Penis of the Tortoise to show its internal Structure. (*After Bojanus.*)

10, tendinous floor of urethral groove; 55′, tendinous insertions of the retractor muscles of the penis; *f*, tendinous walls of the urethral groove enclosing the peritoneal canals; *e*, lateral cavernous substance of the penis; 4, median cavernous substance separated from the preceding by the tendinous septum 9; 5, urethral groove bounded on each side by the cavernous bodies.

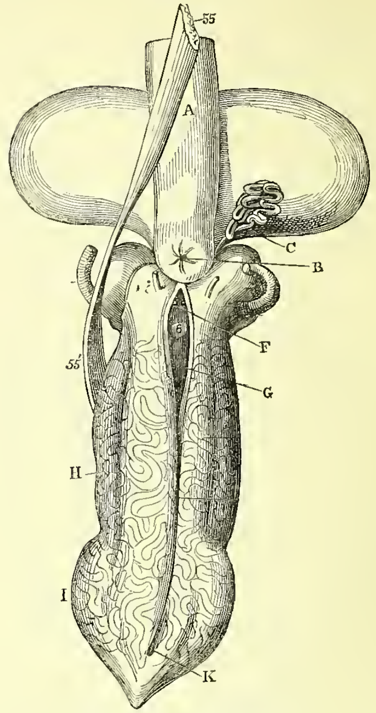
The penis of the Chelonians is furnished with two retractor muscles (*fig.* 239. 55), which arise from the pelvis, and are prolonged as far as the under surface of the glans; these fold up the organ into the cloaca in such a manner that it closes up the orifice of the rectum, and also that of the urinary bladder, as in the ostrich.

Erection is doubtless produced by the action of the sphincter muscle of the cloaca.

In *Crocodiles* the penis is likewise single, and not enclosed in a sheath like that of other Saurians and of Ophidians. This penis is conical in shape, and is grooved along the whole length of its dorsal region by a deep urethral furrow: it is principally composed of a fibrous and elastic corpus cavernosum, the texture of which is very firm. That portion which represents the glans is softer than the rest, being composed of vascular and erectile tissue: it advances above the apex of the corpus cavernosum, and is prolonged beyond it, so that there are two points thus formed, one situated above the other; these points are united together on each side, and also in the middle by a vertical septum which divides the interspace between them into two culs-de-sac. The urethral groove is continued as far as the extremity of the upper point.

The substance of this penis is, generally speaking, solid, and composed of a very dense fibrous substance, without any intermixture of erectile tissue; in this respect the penis of the crocodile resembles that of the ostrich. There is no erectile tissue discernible except at the root of the corpora cavernosa,

Fig. 239.



The Penis of the Tortoise.

A B, the rectum; C, vas deferens; F, terminations of the vasa deferentia, in the commencement of G, the urethral groove; H, corpus cavernosum; I, the glans penis; K, end of urethral groove; 55′, retractor muscle of the penis.

from which part it is continued along the sides of the urethral fissure as far as the glans, the substance of which it principally forms.

The peritoneal canals, which exist in the crocodiles as well as in the Chelonian reptiles, do not in the former enter into the composition of the penis, as they do in the latter; they merely pass along the base of the penis to open into the cloaca by a wide orifice: neither have they in their course any communication with the body of the penis; an arrangement very different from that described above as existing in the tortoises, where they terminate in a cul-de-sac in the substance of that organ.

In the other Saurians the penis is either doubled or bifurcated, each portion consisting of a conical or cylindrical portion which forms a sheath that during erection becomes unrolled like the finger of a glove, in such a manner that what before constituted a cul-de-sac becomes, when developed, the extremity of the penis. When thus developed, the two penises protrude from the two lateral commissures of the lips which bound the transverse opening of the cloaca; when thus protruded, they are generally found to be studded

with recurved spines (*fig.* 233, *k*). Essentially, these organs are merely a derivation from or a modification of the skin, which is here lined with erectile tissue. When in a state of repose, these organs are inverted and retracted beneath the skin of the tail, immediately behind the anus.

Each penis is provided with a special muscle derived from beneath the first caudal vertebra; this muscle is inserted into the bottom of the pouch when the organ is retracted, and serves to retain it in this position.

The contraction of the muscles of the tail contributes with the state of erection to make them protrude from the opening of the cloaca.

It seems to be an axiom universally applicable, that in those genera of reptiles having the external opening of the cloaca placed transversely, a double penis exists, constructed upon the principle above described.

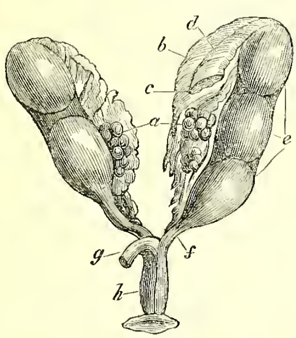
Each lateral penis has a longitudinal groove that extends from its base to its extremity, the extremity of which, when the organ is in a state of erection, is continuous with a groove in the cloaca.

In those reptiles that have the extremity of the penis bifurcated, as, for example, rattlesnakes (*fig.* 233, *k*), the urethral groove likewise bifurcates, sending a branch along each division as far as its extremity.

The armature of the glans varies in different genera; sometimes it is smooth or simply covered by papillæ, or it may be covered with finely pointed spines or cartilaginous plates.

Female Generative Organs. — The reproductive organs in the female reptilia are constructed upon a plan of great simplicity, consisting merely of the ovaria and oviducts, through which the eggs are conducted out of the body. The *ovaria* are two in number, and are found situated upon the sides of the spine in the thoracico-abdominal cavity, where they are suspended by a fold of peritoneum, by which they are invested; they are situated further backward or forwards in the different orders, according to circumstances. In the Chelonians they are symmetrical upon the two sides, and their shape is flattened, broad, and short; but in the elongated bodies of many lizards, and more particularly in the Ophidians, these organs are long and narrow, and their right ovary is situated considerably in advance of the left.

Fig. 240.



Female Generative Organs of Lizard.

a, ovaria; *b*, meso-oviduct; *c*, opening of fallopian tube; *d*, oviduct; *e*, ova contained in oviduct; *f*, termination of oviduct; *g*, rectum; *h*, cloaca.

The ovaria of reptiles are constructed in accordance with two different types, each of which will require notice. In the Chelonians the structure of the ovaria resembles that of the birds, and has a racemose appearance; the ova, as their development proceeds, becoming pedunculated, so that they hang like a bunch of grapes, by pedicles formed from their calyx; this capsule, when the egg is mature, becomes lacerated along a line that divides the globular ovum, like an equator, into two hemispheres, exactly as in birds, and the ovum escapes into the abdominal cavity, there to be taken up by the oviduct.

In the second type of structure, the ovary forms an elongated sac or tube, in the delicate walls of which the ova are developed. As the ovules become matured, they project more or less into the cavity of the ovary; and when they break loose it is into that cavity they escape, and ultimately make their exit through an opening that is formed at its anterior extremity for that purpose at the proper period. In the former of these kinds of ovary the ovules, in order to escape, have to rupture not only the proligerous membrane or calyx, but also the peritoneal tunic, with which they are enveloped. In the second form, which is common to the Ophidians, the ovules have only to tear through the proligerous membrane, in order to escape into the cavity of the ovary, the peritoneal covering of which gives way at the proper season to allow them a passage out.

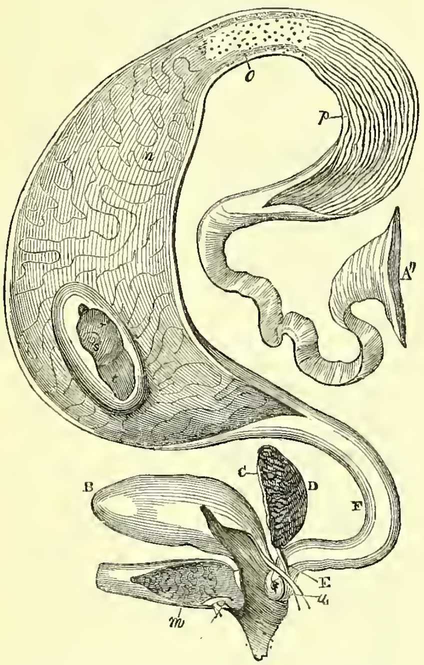
The *oviducts* are invariably two in number, and at their commencement are, as in all other vertebrata, completely detached from the ovary. Each oviduct is a membranous tube which is connected by means of a broad mesenteric fold of peritoneum to the side of the vertebral column; it commences by a wide aperture, by which the ovule is taken up; its walls are at first extremely thin and delicate, but subsequently become thicker and present a glandular appearance. The oviducts of reptiles are proportionally longer than in birds, but they are much puckered and folded up when in the unimpregnated state. Each oviduct is retained *in situ* by a broad peritoneal fold, which performs the functions of a mesentery.

The two oviducts in all reptiles open separately into the cloaca, which thus represents the vulva of mammiferous animals, giving passage to the ova, and likewise receiving the seminal fluid of the male during copulation.

During the passage of the ovule through the oviduct, it progressively becomes furnished with additions to its structure, the formation of which is due to the oviduct itself; a circumstance which will account for the ex-

traordinary and apparently unnecessary length of its canal. In the upper part of its course, the walls of the oviduct secrete the albumen, in which the yoke becomes enveloped, and subsequently the membrana putaminis and the egg-shell are supplied by its inferior portions. In correspondence with these changes of function, its lining membrane is found to differ in appearance and structure in different regions of the oviduct. Towards the commencement of that canal (*fig.* 65, *p*), it is exceedingly

Fig. 241.



Oviduct of Emys Europæus. (*After Bojanus.*)

A'', commencement of oviduct; *n o p*, canal of oviduct laid open; *s t*, ovum contained in lower part of oviduct, broken to show the yolk, the albumen, and the egg-shell; B, allantoid bladder; C D, kidney; E, ureter; F, oviduct; *u*, termination of oviduct; *m*, termination of the opposite oviduct laid open.

delicate, gathered into longitudinal folds, and covered with vibratile cilia lower down (*o*); the walls of the oviduct become evidently glandular, and towards its termination (*n*), where the outer investments of the egg are secreted, it is thrown into broad irregular rugæ, which are continued as far as its termination in the cloaca (*m*). External to the mucous membrane, there is a stratum of muscular fibres, by the contractions of which the ovum is propelled along the oviduct; and externally it is invested with a peritoneal tunic that extends throughout its whole length.

The oviducts in the reptilia are very extensible, and in many genera are constructed to contain numerous ova at the same time, as for example in lizards (*fig.* 240, *e*). In serpents, owing to the slenderness of their bodies, the numerous ova thus contained in the oviduct are arranged in a very remarkable manner: those lodged in the right oviduct correspond with an unoccupied space in the left, and vice versâ those in the left are lodged in an interspace between the ova contained in the right.

The reptilia proper differ in a very important particular from the Amphibia in the manner in which their eggs are fecundated: in the latter, the fertilisation of the ova is effected after their exclusion, so that the envelope of the egg consists merely of a thin chorion: but in the former, where impregnation takes place internally, the ova, after being fecundated, are provided with an external covering, the nature of which varies in different races. Among the Chelonian reptiles, the land and fresh-water tortoises produce eggs covered with a hard calcareous shell like that of birds; but in the turtles, the outer shell remains soft, presenting a texture something like that of parchment.

In crocodiles the egg-shells are calcareous and brittle, but in the generality of Saurians they are flexible and pergamentaceous. In the Ophidians the egg-shells are made up of superposed layers of soft membrane, secreted by the walls of the oviduct.

Some reptiles are generally but improperly styled viviparous. The common viper, for example, derives its name from the circumstance of its sometimes producing its young alive. In this, and in all similar instances, however, such an occurrence is merely fortuitous, and depends upon the length of time the eggs are retained in the oviduct prior to their expulsion. If they are not expelled before the young are hatched, of course the creatures bring forth their progeny alive; and the same animal may, from the nature of its food, be made to produce eggs at one time and living animals at another.

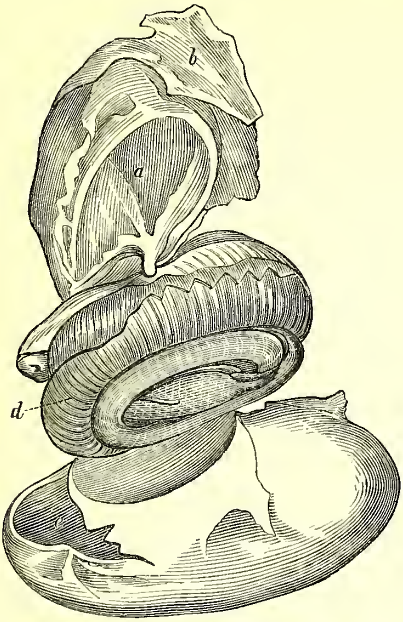
The females of those reptilia whose males are provided with a single penis are furnished with a *clitoris*, but in those genera which have the penis double or invaginated, this organ is deficient. In the female Chelonians the clitoris has very much the same structure as the penis of the male, from which indeed it only differs in its smaller proportional size: it is long, grooved throughout its whole length along its dorsum, and terminated by rounded glans on each side: it contains peritoneal canals similar to those of the male, and is moreover provided with muscles resembling those of the male penis, by which it is retracted into the cloaca.

The female crocodiles have likewise a clitoris very similar to the male penis, but of much smaller proportional dimensions.

Development of the Embryo. — As relates to the internal structure of the egg, and development of the embryo, the Reptilia differ in no essential circumstance from the warm-blooded Ovipara. Within the calcareous or pergamentaceous egg-shell there is a considerable quantity of exceedingly transparent albumen, which so completely fills the shell that no air bubble is to be detected in its

interior, except after some of the fluid contents have been permitted to evaporate. The

Fig. 242.



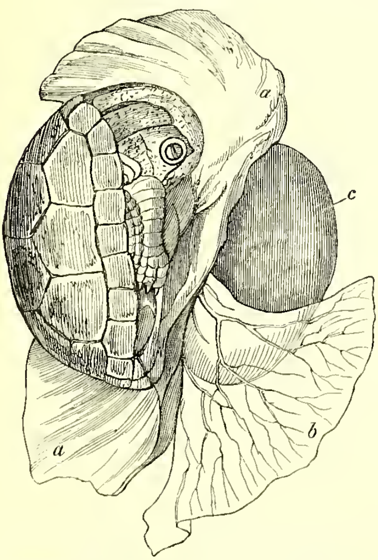
Egg of the Monitor laid open at a late period of Incubation.

a, the yolk; *b*, the amnion; *e*, umbilical cord; *d*, the embryo, remarkable for the beautiful "packing" of its limbs and tail; *e*, the pergamentaceous egg-shell. (*After Carus.*)

vitellus exhibits a cicatricula, surrounded with a double zone.

When the embryo arrives at a sufficient

Fig. 243.



Embryo of Emys amazonica. The shell has been removed and the membranes of the egg laid open and spread out.

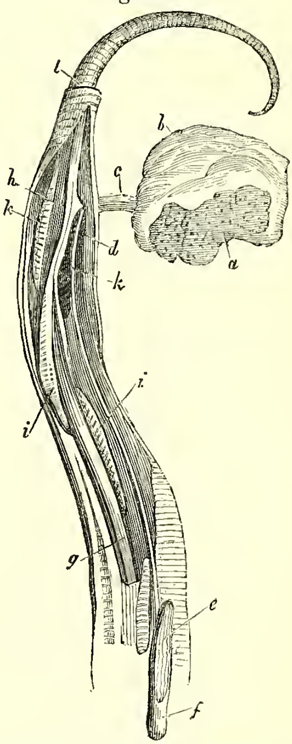
a, the amnion, turned back so as to display the fetus, here represented with its limbs folded up in their natural position; *b*, the allantois, with its enclosed ramifications of blood-vessels; *c*, the yolk, which is in communication with the intestinal canal by means of the vitelline duct, which enters the abdomen through the opening of the navel.

state of maturity, the disposition of the allantois and of the vitelline sac is found to be precisely similar to that of these structures in the egg of a bird, as will be at once evident on reference to the annexed figure, representing the anatomy of the ovum of the Monitor at a very advanced state of maturation.

The allantoic sac, which serves for the respiration of the embryo during the earlier stages of its growth, is richly vascular, and communicates as usual with the anterior part of the cloacal cavity, the so-called urinary bladder being, in fact, merely a remnant of this apparatus.

The vitelline sac communicates freely with the abdominal cavity at the umbilicus, its contents being conveyed into the commencement of the intestinal canal through a ductus vitello-intestinalis (*fig.* 244, *e*): at a still later

Fig. 244.



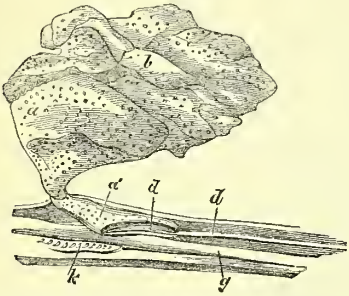
Anatomy of a very young Fetus of the Viper (Vipera Berus). (After Otto.)

a, the yolk-bag, *b*, the amnion; *c*, the umbilical cord; *d*, ductus vitello-intestinalis; *e*, opening of the ductus vitello-intestinalis between the longitudinal folds of the mucous membrane of the small intestines; *f*, intestine partially laid open and cut across; *g*, *h*, continuation of the intestine as far as the anus; *i*, *i*, rudiments of the ovaria; *k*, *k*, the kidneys; *l*, anus.

period the vitelline sac, together with its remaining contents, is gradually taken into the cavity of the abdomen through the umbilical aperture, and before the egg is hatched has entirely disappeared.

In Fig. 246. the condition of these parts is

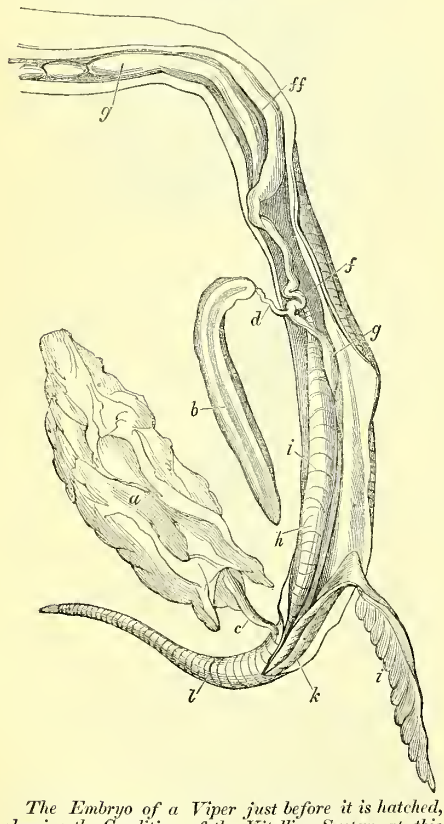
Fig. 245.



Vitelline apparatus of the Fetus of a Viper at a more advanced period, showing the Yolk partially entered into the Abdominal Cavity.

a, the yolk-bag; *b*, the amnion; *a'*, portion of the yolk-bag which has passed through the umbilical canal into the cavity of the abdomen; *d, d*, ductus vitello-intestinalis running forward to open into the intestine; *g*, continuation of intestinal tube; *k*, the kidney.

Fig. 246.



The Embryo of a Viper just before it is hatched, showing the Condition of the Vitelline System at this Period.

The letters *a, c, g, h, l*, indicate the same parts as in *fig.* 244.; *b*, remains of the vitelline sac, taken out of the abdominal cavity, in which it had now become completely closed; *d*, the ductus vitello-intestinalis shrunk into a very short canal; *f, f*, the stomach; *h, i*, rudiments of the ovaria; *k*, the kidney.

represented as they appear just before the egg is hatched, the vitelline sac being already completely introduced into the abdominal cavity; the yolk of the egg, *b*, now reduced to a very small size, is now seen to communicate with the intestine *f, g*, by the extremely short passage, *d*, to which the long ductus vitello-intestinalis, represented in Fig. 244., is now reduced.

Tegumentary System.— In all reptiles the blood is cold, and the general temperature of the body corresponds with the imperfectly oxygenated state of the circulating fluid; instead, therefore, of being clothed in hair or feathers, their bodies are invested with plates or scales of horny cuticle, better adapted to their manner and mode of life. In lizards the cuticular covering is cast off at intervals in small detached portions; but in serpents, where it forms a thin continuous stratum that envelopes the whole surface of the body, it is cast off in a single piece.

Beneath the cuticle, the skin of reptiles presents the usual structure, consisting of the corium, and of an interposed mucous layer, upon which the various colours of the surface of the body depend, which in some species are of great brilliancy.

The chameleon and other lizards are remarkable for the changes of colour of which the surface of the body is susceptible, in accordance with the intensity of the light to which it is exposed, or the nature of the locality in which it happens to be placed. These changes seem to a considerable extent to be voluntary, and under the control of the animal; and various hypotheses have been framed in order to account for them, but without any very satisfactory result.

In the rattlesnakes (Crotalus) the cuticle in the vicinity of the tail presents a very peculiar modification of structure: instead of forming imbricated scales, as in other parts of the body, it is arranged in a series of rings loosely connected together, so as to constitute the remarkable rattle which characterises these dangerous snakes. This singular organ is made up of many pieces, from one to thirty or more, which are perfectly similar to each other in their form, and are articulated together by a very beautiful mechanism.

The piece of the rattle immediately connected with the body seems to be moulded on the last vertebra of the tail, which it encloses, and from which it is only separated by an interposed layer of the dermis or true skin, by which it is secreted. Its surface presents three circular elevations corresponding to three protuberances: of these the first, or that nearest to the body of the animal, is the largest; the other two rings are encased in the succeeding piece, which is connected

in a similar manner to the next ring, and so on throughout the series, the posterior two-thirds of each ring being embraced by the following, so that of the three prominent rings that project from each piece the anterior only is visible, the two posterior being contained in the next ring, with the exception of the ultimate one.

The two last rings of each piece thus enclosed in the two first of the succeeding retain it in its place; but as the diameter of the former is less than that of the latter, each piece is quite loose and plays freely about upon that which it envelopes. None, except the first, are connected with the skin of the animal by any muscle, nerve, or vessel. It is, therefore, merely an external appendage, moved, as any foreign body would be, when the end of the tail is agitated.

The pieces of the organ are formed successively on the skin of the tail, receiving from it the materials necessary for its development, and adhering to it until its growth is complete. A second piece, entirely similar to the first, is formed under it, and detaches it from the end of the tail. It is pushed backwards, leaving between its edge and the skin of the tail an interval occupied by the first ring of the new piece, of which the second and third rings are covered by the first piece. The latter is retained by this connexion, but plays freely round the first piece. A third piece is formed under the second, as that was under the first; pushing the second backwards, but retaining it by its two posterior rings being included in the cavity of the second piece.

If the vertebræ of the tail continue of uniform diameter, all the pieces will be of the same size, and the rattle, consequently, is of one breadth throughout. On the contrary, if the vertebræ grow while the rattle is being formed, the pieces increase in size, and thus the rattle tapers to its end.

It is evident from the preceding description that one piece only can be formed at each partial moulting of the end of the tail; but as we do not know whether these moultings coincide with the general separation of the epidermis from the body, nor the period of their recurrence, the number of pieces not only affords no proof of specific difference, but also indicates nothing about the age of the animal.*

Musk-gland of the Crocodile.— In crocodiles there is a peculiar gland lying under the skin of the lower jaw, on each side about its middle. It is small, of a homogeneous whitish tissue, and is covered by a tendinous sheath. It secretes an unctuous blackish-grey fluid, smelling most strongly of musk, which accumulates in a small bag that opens externally by a wide orifice.

Anal glands have also been observed in the crocodile and alligator, as well as in several serpents: they are of considerable size in female colubers, and are situated under the tail, behind the cloaca, near the part occupied by the penis of the males. They contain a thin yellow substance of a very peculiar odour.

* Lacepède, Hist. Nat. des Serpens.

Bojanus (Lud. Hen.), Anatome Testudinis Europeæ. Fol. Viln. 1819—21. *Mohring* (C. A.), Diss. inaug. zoot. sistens Descriptionem Trionichos Ægyptiaci osteologicam. 4to. Berol. 1825. *Tiedemann* (F.), Anatomie und Naturgeschichte des Drachens. 3 Kpfn. 4to. Nürenb. *Tyson* (Ed. M. D.), Anatomy of the Rattlesnake. 4to. Lond. 1751. *Hellman* (Aug.), Ueber den Tastsinn der Schlangen. 12mo. Götting. *Cloquet*, Mémoire sur l'Existence et la Disposition des Voies lacrymales dans les Serpens. 4to. Paris, 1821. *Cuvier*, Récherches sur les Ossemens fossiles. 4to. Paris, 1821—24. *Home* (Sir Everard), Lectures on Comp. Anat. 4to. Lond. 1814—28. *Sömmering* (Detmar. Guil.), De Oculorum Hominis Animaliumque Sectione horizontale Commentatio. Fol. Götting. 1818. *Brandt* (J. F.) und *Ratzburg* (I. F. C.), Darstellung und Beschreibung der Artzneygewachse, welche in die neue Preussische Pharmacopæ aufgenommen sind. *Carus*, Lehrbuch der vergleichenden Zootomie. 1834. *Owen*, Odontography. *Wagner*, Prodromus. Fol. *Cuvier*, Anatomie Comparée. Last edition. 8 vols. 8vo. Paris, 1840. *Schlegel*, Essai sur la Physiognomie des Serpens. Amst. 1837. *Meckel*, Syst. der vergleichenden Anatomie. *Perault*, Mém. de l'Acad. des Sciences, tom. iii.

(*T. Rymer Jones.*)

RESPIRATION (Germ. *Athmung*).—Before the nutritious juices of organized bodies can be properly elaborated and rendered fit for maintaining the vitality of the tissues through which they move, it is indispensable that certain chemical changes take place between them and the atmospheric air. All organized bodies, therefore, vegetable as well as animal, require a supply of atmospheric air for the continuance of life, and the amount of this is proportionate to the number and energy of their vital actions. These chemical changes between the nutritious juices of organized bodies and the atmospheric air constitute the important function of Respiration.

In studying the chemical actions that occur in respiration in different organized bodies, it is necessary to keep in mind the constitution of the atmospheric air, both in its free state and when dissolved in water. The atmospheric air, in its free state, is, as is well known, chiefly composed of nitrogen and oxygen, in the proportion of about 21 parts of oxygen to 79 of nitrogen by volume; or by weight, in the proportion of 23·1 of oxygen to 76·9 of nitrogen. Dumas and Boussingault, in their accurate experiments *, found the average proportion of these gases to be, by volume, 20·81 of oxygen, and 79·19 of nitrogen †; or by weight, 23·01 of oxygen, and 76·99 of nitrogen. The quantity of carbonic acid gas in the atmospheric air is very much smaller than that of the oxygen and nitrogen. Theod. De Saussure ‡, in his experiments,

* Annales de Chimie et de Physique, troisième série, tom. iii. p. 257. 1841.

† Or, what would be sufficiently accurate, 20·8 oxygen and 79·2 nitrogen.

‡ Annales de Chimie et de Physique, tom. xxxviii. p. 411. 1828.

found the maximum quantity of carbonic acid gas in 10,000 parts of atmospheric air to be 6·2, the minimum 3·7, and the average 4·9 or nearly 1 part, by volume, of carbonic acid gas in 2000 parts of atmospheric air. Results similar to those procured by Saussure, who experimented at Geneva, have been obtained by Boussingault* and Thenard† at Paris, Brunner‡ at Berne, and Verver§ at Groningen in Holland, so that we have the strongest grounds for believing in their general accuracy. The variable quantity of watery vapour that exists in the atmosphere must also be taken into account in examining the function of respiration. A quantity of ammonia, so small however that its usual proportion cannot be ascertained, is constantly present in the atmospheric air, which, when it descends to the earth dissolved in water, serves, according to Liebig, an important purpose in the nutrition of vegetables. There are, besides the above substances, numerous others in the gaseous form, exhaled from the surface of the earth, too minute to be detected by analysis, but sometimes recognised by their effects upon the living organism. No doubt the miasmata and effluvia, which can inflict such disastrous evils on the human race, are diffused through the atmospheric air.

Though the proportions of the three gases, viz. nitrogen, oxygen, and carbonic acid, usually regarded as forming the constituent parts of our atmosphere, are not quite uniform at all times and in all places, chiefly from local disturbing causes, yet these differences are to a small extent, when its free circulation is permitted. Dalton || maintained, that in elevated regions the proportion of oxygen to azote is somewhat less than at the surface of the earth; but this is not confirmed by the more recent experiments of Dumas, Boussingault, and Brunner. In the experiments of Lewy ¶ and Morren **, the composition of the air near the surface of the sea differed in its amount of oxygen from that over the land. Saussure detected a somewhat smaller quantity of carbonic acid gas in the air during the day than during the night *, and a larger quantity in the air of the town of Geneva than in that taken in the country three-fourths of a league distant, in the proportion of 100 to 92; and Boussingault and Lewy, in their later experiments, observed a similar difference between the air taken from the densest parts of Paris and that of the country.† Lewy detected a considerable increase of carbonic acid gas, no doubt of volcanic origin, in the air of Guadaloupe, but without any diminution in the usual relative proportions of the oxygen and nitrogen.‡ As a portion of the oxygen of the atmospheric air is combined with carbon to form carbonic acid gas in the respiration of animals, in ordinary combustion, and in numerous other chemical processes going on at the earth's surface, it is obvious that when individuals of the human species are surrounded by a limited quantity of air which is not renewed so rapidly as it is vitiated by respiration, the proportion of oxygen gas will be diminished and the carbonic acid increased, and this the more rapidly if any other process of deoxidation of the confined air be at the same time in operation. Dalton analyzed the air of a room where 50 candles had been kept burning and 500 people had been collected for two hours, and found that it contained 1 per cent. of carbonic acid gas.§ Leblanc made a number of analyses of the air taken from the rooms of some of the public buildings in Paris. || He collected some of the air of one of the wards of La Pitié, the area of which was 70,632 cubic feet, containing 54 patients, after it had been shut during a whole night, and procured from it 3 parts of carbonic acid gas, by weight, in the 1000, or about 5 times as much carbonic acid as is usually present in the atmosphere.¶ The oxygen gas had suffered a corresponding diminution. In one of the sleeping apartments of the Salpetrière, the carbonic acid gas amounted to 6 parts, by weight, in the 1000 parts of the contained air, and in another sleeping apartment to 8 parts in the 1000.** In the Amphitheatre of Chemistry at the Sorbonne, the air collected at the end of the lecture furnished 10·6 of carbonic acid, by

* Annales de Chimie et de Physique, tom. x. p. 456. 1844.

† Referred to in opus supra citatum, tom. x. p. 463. 1844. Thenard's experiments were made prior to those of Saussure.

‡ Opus supra cit. tom. iii. p. 313. 1841.

§ Referred to in opus supra cit., tom. x. p. 462. 1844.

|| London and Edinburgh Philosophical Magazine and Journal of Science, vol. xii. p. 406. 1838.

¶ Annales de Chimie et de Physique, tom. viii. p. 425. 1843. Lewy found the quantity of oxygen in the air near the surface of the North Sea on an average 22·6 by weight in the 100 of air, while the air over the land contained 23 of oxygen in the 100.

** Annales de Chim. et de Phys., tom. xii. p. 5. 1844. Morren states that the air resting upon the surface of the sea, in calm weather, may contain from 23 to 24 parts, by volume, of oxygen instead of 20·8, the usual quantity; and this increased quantity of oxygen, under the circumstances mentioned, is connected, as we shall see immediately, with the action of the marine vegetation upon the atmospheric air. The experiments of Lewy and Morren are not contradictory; for in those of the former the air was taken from the surface of the deep sea at some distance from the shore, and in those of the latter the air analyzed had been resting for some time over pools of sea-water abounding in algæ, exposed to the sun's rays.

* Boussingault (opus cit. tom. x. pp. 464, 465) obtained similar results; but he admits that more extended observations are required on this point.

† Annales de Chim. et de Phys., tom. x. p. 470. 1844.

‡ Idem opus, tom. viii. p. 450. 1843.

§ London and Edinburgh Philos. Mag., vol. xii. pp. 405, 406. 1838.

|| Annales de Chim. et de Phys., tom. v. p. 223. 1842.

¶ If the usual quantity of carbonic acid in the atmosphere be from 4 to 6 in the 10,000 parts by volume, that is equal to from 6 to 9 of carbonic acid gas by weight.

** Opus cit., p. 233.

weight, in the 1000. The air collected in the pit of the Opéra Comique a short time before the termination of the performance contained 2·3; while in another experiment the air from one of the boxes contained 4·3, by weight, of carbonic acid gas in the 1000. In one of the stables at the Ecole Militaire, the air collected after it had been kept closed for a night yielded 1·05 in the 100; and the air from another which was better ventilated yielded about 2 parts in the 1000, by weight.* If, according to the opinion of Leblanc and others, carbonic acid gas exerts a prejudicial effect upon the vital actions in the human species when it has accumulated to the extent of 1 per cent. in the air to be breathed, the above facts, to which many others might readily have been added, point out the importance of securing sufficient ventilation both in our private and public buildings.

As the gases held by water in solution supply the means of aquatic respiration to many animals and plants, a knowledge of the quantity and composition of these gases is also necessary for the full comprehension of the function of respiration. Humboldt and Gay Lussac state that the water of rivers, and distilled water well aired, hold in solution about $\frac{1}{25}$th of their volume of air composed of about 32 of oxygen and 68 of azote, by volume.† Morren ‡ concludes from his experiments that sea-water contains in solution between $\frac{1}{45}$th and $\frac{1}{30}$th of its volume of air, a quantity sensibly less than that obtained from fresh-water, which usually contains from $\frac{1}{30}$th to $\frac{1}{25}$th, or even $\frac{1}{20}$th of its volume.§ He found that the air obtained from fresh-water under ordinary circumstances, whether distilled and again perfectly aërated, or the limpid water of a moderately rapid stream, contains 32 parts of oxygen, and from 2 to 4 of carbonic acid, by volume, in the 100; while the air obtained from sea-water yielded 33 of oxygen and from 9 to 10 of carbonic acid in the 100. The relative proportion of the gases obtained both from fresh and sea-water varies considerably under certain conditions. In fresh-water ponds abounding in plants or green animalculæ, and in shallow parts of the sea, where numerous algæ flourish, the proportion of oxygen gas may be considerably increased during sunshine, especially if the water be at the same time still. Morren analyzed, in a bright day in July, the gas dissolved in the water of a fish-pond of a green colour, chiefly from the numerous animalculæ it contained, and found in that procured in the morning 25, at mid-day 48, and in the evening as much as 61 of oxygen in the 100 parts.* Similar changes, but to a less extent, were detected by Morren in the air of sea-water, and they are chiefly dependant upon the action of the algæ. In one experiment, performed on a fine sunny day, when the sea was at the same time calm, the air obtained from the water yielded 40 per cent. of oxygen in the early part of the day, and 53·6 in the evening. The total quantity of air obtained from both kinds of water varied at different times of the day; and its increase was chiefly dependant upon the addition of oxygen, the carbonic acid at the same time suffering a decrease, but not in the same proportion, while the nitrogen † seemed to suffer little change. This increase of oxygen will partly contribute to the supply required for the respiration of the numerous aquatic animals which usually frequent the localities where it is evolved, and be partly given off to the superincumbent air, and thus assist in maintaining the purity of the atmosphere.

Notwithstanding the large quantity of oxygen daily removed from the atmosphere by the respiration of animals and other causes, yet from the great extent of the atmosphere, and the rapid mixture of its different parts, a long period of time must necessarily elapse before it suffers any marked deterioration, even were there no compensating operation in the vegetable kingdom. The oxygen gas in the atmosphere is equal in weight to a column of 7·8 feet of water pressing upon every part of the earth's surface: and it has been stated that it would require 10,000 years, supposing the earth peopled with 1,000,000,000 of men to produce a perceptible effect upon the eudiometer of Volta, even though vegetable life was annihilated; and that to suppose *all the animals* on the surface of the earth could by

* According to the experiments of M. Lassaigne (Comptes Rendus, 13th Juillet, p. 108. 1846) the carbonic acid gas, formed by respiration in apartments where the ventilation is very imperfect, is not confined to the parts nearest the floor, but is diffused nearly in equal proportions through every portion of the mass of air in the apartments.

† Journal de Physique et de Chimie, par Delamitherie, tom. lx. p. 158. The percentage of oxygen from the air of water of the Seine was 31·9; of distilled water which had again absorbed air, 32·8; and of rain water, 31·0. (p. 159.)

‡ Annales de Chim. et de Phys., tom. xii. 1844.

§ M. Lewy (Comptes Rendus, 28th Sept. 1846) states that, in his experiments, one litre (61·027 cubic inches English) of Seine water yielded about 40 cubic centimetres (2·440 cubic inches) of air, and the same quantity of water from the ocean furnished only 20 cubic centimetres (1·220 cubic inches). The water of the ocean, in consequence of the salts it holds in solution, absorbs much less atmospheric air than fresh water.

* Opus cit. p. 9. Wöhler (Poggendorff's Annalen der Physik und Chemie, band lvii. S. 308. 1842) analyzed the gas exhaled from the greyish yellow mass, consisting in a great measure of living infusoria mixed with some confervæ, which collects in a salt spring at Rodenberg in Hesse, and found it to be composed of 51 per cent. of oxygen, and 49 of nitrogen.

† M. Lewy (Comptes Rendus, 28th Sept. 1846) has observed similar changes, but not to the same extent, in the relative proportions of oxygen and carbonic acid in the air of sea-water under the circumstances mentioned by Morren. According to the results of Lewy, the waters of the ocean contain a small quantity of sulphuretted hydrogen gas, apparently evolved from the bodies of certain molluscous animals, which may be imparted to the air resting upon the surface of the water; and Dumas, in his report upon Lewy's Memoir, throws out some remarks on the possibility of the sulphur contained in this gas serving an important purpose in the nutrition of plants.

their respiration deteriorate the air to the extent of removing in a century the 8000th part of the oxygen in the atmosphere, is to make a supposition very much beyond the truth.*

Respiration of plants. — The results of the chemical actions between the atmospheric air and the vegetable kingdom, are chiefly influenced by the presence or absence of light, and the condition of the plants at the time. When a plant is surrounded by the ordinary atmospheric air, and exposed to the sunshine, the green parts of the plant, and especially the leaves, decompose the carbonic acid contained in the atmosphere, seize upon the carbon, and liberate the oxygen; while the same plant in the dark, not only ceases to decompose carbonic acid, but actually exhales into the surrounding atmosphere a portion of this gas. A quantity of nitrogen gas is also given off by plants along with the oxygen.† Plants, therefore, during exposure to light, purify the air by removing carbonic acid and adding oxygen, while during the night they, like animals, deteriorate the air by exhaling carbonic acid gas. As, however, the quantity of oxygen gas liberated during the day from the decomposed carbonic acid is more than sufficient to counterbalance the quantity of carbonic acid formed during the night, plants on the whole must counteract, either entirely or in part, the accumulation in the atmosphere of the carbonic acid gas formed by the respiration of animals, and in various chemical processes going on at the earth's surface. Indeed, nearly the whole of the carbon which enters so largely into the formation of the vegetable tissues, appears to be obtained through the decomposition of the carbonic acid of the atmosphere.

The parts of a plant which are not of a green colour, such as the roots, &c., absorb oxygen from the atmosphere, and give out carbonic acid gas even in the sunshine; and this process seems essential to the vigorous growth of the plant. The flowers of a plant also absorb oxygen, and exhale carbonic acid, and the quantity of the latter gas evolved during inflorescence is considerable. The seeds of plants during germination also absorb oxygen and give out carbonic acid.‡ The Fungi evolve carbonic acid gas in large quantity from all parts of their structure, and at all periods of their growth, even when exposed to a bright sunshine, and these plants derive their supply of carbon from the soil in which they grow.* It is also maintained that a quantity of oxygen is absorbed by the surface of plants during spring and summer, to assist in the elaboration of their acids, resins, and volatile oils. We thus perceive that the chemical actions between the atmospheric air and plants are varied, and differ in some important respects from those that occur in animals. Attempts have been made to show that the respiratory function is essentially the same in these two great divisions of the organic kingdom; that the fixation of carbon and the liberation of the oxygen gas by the leaves, and other green parts of plants during their exposure to the rays of the sun, form a part of their digestive process; while the evolution of carbonic acid, which proceeds during the day as well as during the night, from seeds during germination, from the flowers, from the surfaces not coloured green, and also, it is asserted, partly from the leaves, is their true respiratory process.† According to others, if the actions of the juices upon the atmospheric air, by which they are changed from the crude to the fully elaborated sap, and rendered fit for the nutrition of the plant, constitute the function of respiration, then the green surfaces, and especially the leaves,

* Dumas' Essai de Statique Chimique des Etres Organisés, p. 18, 3rd edit. 1844; and Dumas and Boussingault in Annales de Chim. et de Phys., tom. iii. p. 288. 1841.

† Daubeny, in Philos. Transactions of London for 1836, p. 149; and Professor Draper, in London, Edinburgh, and Dublin Philosophical Magazine, vol. xxiii. p. 161. 1843. According to Draper, "when the leaves of plants under the influence of light decompose carbonic acid gas, they assimilate all the carbon, and a proportion of oxygen disappears, at the same time they emit a volume of nitrogen *equal to that of the oxygen consumed.*" The greater part of the nitrogen evolved comes, he believes, from the decomposition of some nitrogenized constituent of the leaf.

‡ The animalcula, especially those of a green colour, seem to exert the same effects upon the atmospheric air under the influence of light as the green parts of plants. Vide observations of Morren and Whöler, already referred to; and also Ehrenberg, in Poggendorff's Annalen, band lvii. S. 311.

* Marcet (Bibliothèque Universelle de Genève, (Sciences et Arts,) tom. lvii. p. 393. 1834; and Annales de Chim. et de Phys., tom. lviii. p. 407. 1835) ascertained that Fungi, when confined in a limited quantity of air for some time, disengage a larger quantity of carbonic acid gas than could have been formed by the combination of carbon with the oxygen which has disappeared from the air: that when confined in nitrogen gas, a small quantity of carbonic acid is evolved, and in some cases a small quantity of nitrogen is absorbed; and that when confined in oxygen gas a larger quantity of this gas is absorbed than what is sufficient to constitute the carbonic acid gas evolved, and that this is replaced, at least in part, by a quantity of azote disengaged from the plants. We thus perceive that if certain of the lower organized bodies, generally regarded as belonging to the animal kingdom, effect the same changes upon the atmospheric air by their respiration as the higher vegetables do, there are, on the other hand, certain of the lower organized plants that resemble in this respect the higher organized of the animal kingdom. Other cryptogamic plants having a green colour, such as the Ferns and Algæ, liberate oxygen gas when exposed to the sunshine. Vide Morren's Experiments on Algæ, already referred to; and those of Daubeny, upon Ferns and Algæ, in London Philos. Transact. vol. xlii. p. 166. 1836.

† Burnett, in the Journal of the Royal Institution of Great Britain, vol. i. p. 83. 1831. Mr. Burnett also maintains that the analogy further holds good "between the functions of respiration and digestion in animals and plants, for to both is carbonic acid deleterious when breathed, and to both is it invigorating to the digestive system when absorbed as food," p. 100. Professor Draper (London and Edin. Philos. Magazine, 1844) proceeds still farther, and asserts that the whole of the action of the leaves upon the atmospheric air constitutes a true digestive and not a respiratory function.

are the true respiratory organs of plants.* Besides, it has been alleged that the evolution of the carbonic acid gas from the leaves during the night is not attended by an absorption of oxygen, as in the respiration of animals; that it is a mechanical process, having no connexion with the nutrition of the plant; and that it depends upon the carbonic acid absorbed along with the water by the roots and leaves, escaping into the air along with the water evaporated during the periods when the plant, as in the absence of sunshine, is incapable of fixing the carbon.† As the respiratory process in animals forms a part of the great Nutritive Function, for preparing, elaborating, and assimilating the nutritious juices, and as the two functions performed respectively by the digestive and respiratory organs in the higher animals are not definitely separated in the vegetable kingdom, we can readily understand that the same structures in the vegetable kingdom which carry on the process of respiration, may also at the same time assist in the performance of other parts of the nutritive function.

In some of the lower organized plants every part of their surface is probably equally efficient in the performance of the function of respiration; while in the higher plants, though the whole of the external surface may still aid, the leaves are the chief organs of respiration. Botanists are not agreed as to what extent the spiral tubes, usually regarded as analogous to the tracheæ of insects, act as organs of respiration. These spiral vessels do not form continuous canals, and do not open upon the stomata, so that the air cannot enter them without having previously permeated a greater or less thickness of vegetable tissue covering them. Their share in the performance of the function of respiration cannot, probably, be great.

Respiration in animals. — The function of respiration varies greatly in activity, and in the external form and position of the apparatus by which it is effected, in the different divisions of the animal kingdom. In all animals, except some Infusoria, the nature of the chemical changes between the atmospheric air and the nutritious juices is pretty uniform, and essentially consists in the evolution of carbonic acid gas and the absorption of oxygen. Azote may be exhaled by, or absorbed at, the respiratory organs in small quantities; but these changes seem to be of secondary importance in the function of respiration, do not appear to be uniform in the same animals at different times, and occasionally cannot be detected. The evidence, however, preponderates in favour of the opinion that a small quantity of azote is exhaled at the respiratory organs.

The function of respiration in animals includes two distinct processes — the evolution of one gas from the nutritious juices, and the absorption of another; and while the former is an act of excretion necessary for the maintenance of the purity of the nutritious juices, the latter is an act of absorption necessary for their proper elaboration. These two acts are of equal importance in supporting the vitality of the organism, are so closely linked together, and are so reciprocally dependent for their continued action, that they have been regarded as belonging to the same function, though in a logical point of view they are parts of two distinct functions, viz. 1st, the absorption by the organism of new materials from the surrounding media for completing the elaboration of the nutritious juices; and, 2dly, the excretion from the organism of those substances which are of no further use, and would even prove prejudicial if retained. Many of the definitions given of the respiratory process are liable to strong objections in consequence of its compound character not having been kept strictly in view. These mutual actions between the nutritious juices and atmospheric air are purely chemico-physical, take place wherever the air and the fluids are brought into contact, and do not require the agency of vitality for their manifestation. When a urinary bladder has been filled with venous blood and placed in atmospheric air, the oxygen of the atmospheric air, and the free carbonic acid in the blood, mutually permeate the coats of the bladder, the oxygen gas being absorbed by the blood, and the carbonic acid escaping into the surrounding atmosphere. This interchange depends upon the strong tendency that different gases have to intermix or diffuse themselves through each other, and as this action in this particular case takes place through a permeable membrane, it may be regarded as a kind of endosmose and exosmose.

It necessarily follows, that wherever the nutritious juices of organized bodies are separated from the atmospheric air by tissues permeable by oxygen and carbonic acid gas, the function of respiration may be performed. The energy of this function will be regulated by the following conditions: — the greater or less thickness and permeability of the tissues interposed between the atmospheric air and the nutritious fluids; the quantities and constitution of these substances thus brought into action; the extent of surface over which they operate; and the rapidity with which fresh portions of both are brought into contact, in the place of those whose mutual actions have been completed. In the higher animals, where this function is performed in greatest perfection, the apparatus for effecting it is very complicated and extensive, and consists, 1st, of a special organ — the lungs, affording an immense extent of surface where the blood flows in innumerable minute streamlets only separated by very thin membranes from the atmospheric air; 2dly, of an assemblage of muscles, bones, and nerves, for efficiently renewing the air in the lungs; and, 3dly, of a series of vessels with a contractile propelling organ attached to them — the pulmonary arteries and veins and right side of the heart, — for rapidly

* Cours Elémentaire d'Histoire Naturelle. Botanique par M. A. de Jussieu, p. 177.

† Liebig's Organic Chemistry, translated by Playfair, p. 31. 1840. Hunt's Researches on Light, p. 194. 1844. Dumas' Essai de Statique Chimique des Etres Organisés, 3rd ed. p. 24. 1844.

changing the blood in the lungs, and bringing successive portions of it into contact with the atmospheric air. On the other hand, in some of the most simple forms of animal life, which, with the exception of some of the entozoa, are all aquatic, the function of respiration is effected by the external surface, and they have no special organ for exposing their nutritious juices to the action of the atmospheric air, no apparatus for bringing fresh supplies of the surrounding fluid into contact with their bodies, and no canals or tubes for securing a more rapid change of those portions of the nutritious juices exposed to the action of the atmospheric air.

Numerous and interesting modifications of the respiratory apparatus, each wonderfully adapted to the wants of the individual animal, and the medium in which it lives, and in admirable relation to its other nutritive functions, fill up the wide interval between the most complex and the simplest methods of carrying on the function of respiration. This, like the other functions of the body, is, in proportion to the energy of its manifestations, more concentrated upon individual organs chiefly or entirely constructed for this purpose, and it thus becomes more and more specialized as we ascend in the zoological scale.

The position of the respiratory apparatus is chiefly regulated by the circumstance of the animal being terrestrial or aquatic, or, in other words, by its supply of atmospheric air being in the gasiform condition, or held in solution by water. In the greater number of aquatic animals, the respiratory apparatus is placed on or near the external surface of the body; while, in the terrestrial animals, it is situated more or less deeply in the interior of the body. The medium in which the animal lives also influences the size and complexity of its respiratory organs. As the quantity of atmospheric air in contact with respiratory organs of the same extent of surface must be much smaller in aquatic than in terrestrial animals, a more extended respiratory organ is required in the former than in the latter to effect the same amount of respiration, just as a more extended digestive apparatus is required in herbivorous than in carnivorous animals to extract the same amount of nutritious matters from their food. As water cannot furnish to terrestrial animals an adequate supply of atmospheric air, their vital actions are brought to a stand when their respiratory organs are immersed in that fluid, and this the more quickly in those immediately dependant, as the birds and mammalia, upon large and frequent supplies of atmospheric air. The respiratory organs of aquatic animals are, on the other hand, inadequate for the performance of respiration in the atmospheric air, but from very different circumstances. The most obvious of these are, 1st, their respiratory organs, from their external position, are either freely exposed or only partially covered, so that when they are removed from the water into the atmosphere they become dry in consequence of the evaporation of their moisture, and this the more rapidly as there is little or no provision independent of the water in which they live, for keeping these surfaces moist by a secretion, as in air-breathing animals: 2dly, in those cases where the respiratory organ consists of numerous membranous plates or laminæ that float apart in the water, and have every portion of their external surface bathed in this fluid, removal into the atmospheric air causes them to fall together, so that comparatively a small quantity of their surface is now in contact with the air. In some of the Crustacea, and in some fishes, as the eels, the branchiæ, or respiratory organs, being covered to a great extent, desiccation proceeds slowly, and life may be prolonged for a considerable time in the atmospheric air. In one of the groups of the Crustaceans, the land-crabs or Gecarcinians, though the respiratory organs have a close resemblance to the branchiæ of the aquatic tribes, yet as they inhabit damp situations, and have a provision for keeping the respiratory surface moist, they are enabled to live as terrestrial animals.

It has already been stated that the respiratory apparatus in all the higher animals consists of three distinct parts; — of an expanded membrane, through which the atmospheric air and the nutritious fluid the blood, act chemically on each other; of organs for renewing the atmospheric air in contact with the external surface of this membrane; and of organs for circulating the nutritious fluid along channels placed upon the inner surface of this membrane. Of these three portions of the respiratory apparatus, the first, or the expanded membrane, which may be termed the *respiratory membrane*, is the most essential, and the other two may be considered as merely accessory to it. In those animals, as the Infusoria, the Polypes, &c., that have no special organs of respiration, the surfaces, bathed by the fluids in which they live, act as a *respiratory membrane:* the atmospheric air in the surrounding fluids is there brought into contact with the nutritious juices, and the function of respiration is effected in the feeble manner in which it is manifested in such animals. In those animals possessing special organs of respiration, the respiratory membrane is formed in almost all cases by prolongations, folds, or reduplications of the internal or external tegumentary membrane, and all of these different arrangements are evidently with the view of increasing the extent of surface of that membrane. In the pulmograde Medusæ the margin of the disk, though smooth, and presenting no prolongation of the external tegumentary membrane, acts more efficiently in the function of respiration than the other parts of the surfaces of the body, and may be considered as a respiratory organ, in consequence of a large quantity of the nutritious juices flowing through numerous vessels distributed there. In some of the Echinodermata, as in the star-fishes (*Asteridæ*), and in the sea-urchins (*Echi-*

nidæ), the internal integumentary membrane is materially aided in the performance of this function by the aquiferous canals in the former, and by the peritoneal cavity in the latter; indeed, the peritoneal cavity may be considered the special organ of respiration in the Echinidæ.

The respiratory membrane, in most cases, presents one of three forms, which have received the names of *gills* or *branchiæ*, of *tracheæ*, and of *lungs*. In the gills or branchiæ the tegumentary membrane is prolonged outwards, in the shape of laminæ, tufts, or branches; and this arrangement is found in aquatic animals. This form of the respiratory membrane is not, however, universal in those aquatic animals possessing special organs of respiration. In the Holothuridæ, one of the tribes of the Echinodermata, the chief respiratory organ consists of two aquiferous tubes, of an arborescent form, that open upon the surface of the cloaca.*

In the Ascidians, among the Mollusca, the chief respiratory organ is a large cavity, regarded by some as a dilatation of the œsophagus; and in certain of the aquatic Gasteropoda it consists of a sac, with lamellæ on its inner surface, opening upon the external surface of the body. The small cavities placed along the sides of the body of the leech, and opening externally, are also believed to be respiratory organs.

The arrangement of the respiratory membrane, termed tracheæ, is present in the Articulata, among the Myriapods, insects, spiders, and also, with a few exceptions, among the larvæ of insects living in the atmosphere; and is observed in greatest perfection in the adult insects. It consists of a prolongation of the external membrane into the interior of the body, in the form of tubes, often extensively subdivided and ramified, kept open by fibres rolled round their walls in a spiral manner, and commencing at the external surface of the body by orifices termed *stigmata*. In certain of the larvæ of insects, this arrangement of the respiratory membrane is modified to adapt it for aquatic respiration. In the larvæ of the Ephemera, these tracheæ, instead of terminating in stigmata, are prolonged outwards into a foliaceous expansion of the external integument, where they are subdivided and ramified, and terminate in shut extremities. A constant interchange between the air in the tracheæ of these larvæ, and the atmospheric air dissolved in the water, will go on through the membranes interposed between them.† In the larvæ of the Libella the tracheæ are distributed in a similar manner in a membrane placed within the anus, and the animals draw in and expel the water with considerable force from that cavity, so that these respiratory movements act at the same time in causing locomotion.

The arrangement of the respiratory membrane called *lungs* consists of the prolongation of the tegumentary membrane inwards in the form of sacs, and is destined for aërial respiration. In some of the terrestrial gasteropodous Mollusca, the lung is formed by a single, large, and simple sac, opening by an orifice on the right side of the body. In the Arachnida the lungs are composed of two or more separate cavities, lamellated on their interior, opening on the external surface of the body, and are analogous to the branchial cavity in some of the aquatic Gasteropoda. In all the air-breathing Vertebrata, the respiratory membrane is formed by a prolongation of the internal tegumentary or mucous membrane from the upper part of the digestive tube, and this also holds in the aquatic Vertebrata, or the fishes. When the expanded respiratory membrane is placed at some distance from that portion of the mucous membrane of the digestive tube with which it is continuous, as is especially the case in the Mammalia and birds, this mucous membrane is prolonged to the part where its expansion occurs, in the form of a tube, strengthened on the outer surface by elastic textures to enable it to withstand the atmospheric pressure. Along this tube (trachea), and its branches (bronchi and bronchial tubes), the air passes to and from the proper respiratory membrane on the inner surface of the lungs. In the water newt the lungs consist of a pair of elongated sacs, without any internal laminæ or folds. In the frog these membranous sacs present ridges on their inner surface, especially at the upper part; and in the lungs of the turtle and crocodile these ridges increase in number and in size, and form partitions dividing the interior of the lungs into numerous cells communicating with each other.

In birds the bronchial tubes on entering the lungs have numerous parietal cells on their inner surface; and this extension of the respiratory surface is still further increased by some of the tracheæ opening into membranous bags, often presenting a cellular appearance, and communicating with the interior of certain of the bones. In the lungs of man and the other Mammalia, the bronchial tubes divide and subdivide into minute branches, each of which ends in a cluster of terminal cells, forming one of the small lobes into which the lung may be divided. By this arrangement an immense extent of respiratory surface is packed up in a small space.*

* This form of the respiratory apparatus has been termed *cœlobranchiate* by Straus-Durckheim, being derived from κοῖλος, *hollow*; and βράγχια, *gill*.

† This modification of the tracheal respiratory organ has been designated *tracho-branchiate* by Straus-Durckheim.

* Hales (Statical Essays, vol. i. p. 242. 1769) estimates the inner surface of the whole lungs in the calf at 289 square feet, equal to 19 times the surface of a man's body; and Lieberkuhn calculates (as quoted by Schultz in his System der Circulation, p. 288) that the whole surface of the air-tubes and air-cells in the human species amounts to 1400 square feet. Monro, on the other hand (Essays of Monro Secundus, p. 59. Edinburgh, 1840) calculates that the inner surface of the human lungs is only equal to 440 square feet, or nearly thirty times

In those animals possessing special organs of respiration, this function is not necessarily restricted to these organs; on the other hand, there are generally other parts of the organism which serve as auxiliary organs of respiration. We have already seen that respiration may take place wherever the atmospheric air and the nutritious juices are not separated by tissues impermeable to gases. When these tissues are feebly permeable by gases, or when the quantity of nutritious juices in these tissues is small, their respiratory qualities must be feeble, however abundant the amount of atmospheric air in contact with them may be: while under more favourable physical conditions of the tissues, the amount of respiration effected may be considerable. We can readily understand, therefore, how the external cutaneous surface in fishes and in the batrachian reptiles may considerably assist the special organs of respiration; and how, in some fishes, the mucous surface of the digestive tube may act as an accessory organ of respiration when they rise to the surface of the water, and swallow a quantity of air. As in the crocodiles, and in certain cartilaginous fishes, there are apertures by which the water may enter the peritoneal cavity, it is believed that in these animals the large abdominal serous membrane, which is the chief respiratory organ in the Echinida, serves as an auxiliary organ of respiration.* In fishes the air-bladder, formed by a prolongation of the internal tegumentary membrane, and constituting a rudimentary lung, is generally considered to be an accessory respiratory organ. Even in the higher Mammalia, the external tegumentary membrane, and the internal tegumentary membrane of the digestive tube, but more especially the former, may be regarded as auxiliary organs of respiration, but the aid they afford to the special respiratory membrane in the lungs is so feeble, that in a practical point of view they may in most cases be disregarded, and they can under no circumstances supply the place, even for a brief period of time, of the special respiratory membrane.

A moist condition of the respiratory membrane appears to be essential to the proper performance of its functions, and this is obtained in those animals which breathe atmospheric air, by its deep position, and by the fluid secretions poured out upon its surface.

The structure of that portion of the respiratory apparatus which acts in bringing fresh supplies of atmospheric air into contact with the respiratory surface, is chiefly regulated by the animal being terrestrial or aquatic, and by the amount of respiration required. In many of the lower aquatic tribes the respiratory surface is external and floats in the water, and any movements on the part of the animal, and currents in the water, must change, more or less rapidly, the fluid in contact with the respiratory surface. In such cases, the only *structural* provision for promoting such movements in the water, is the presence of numerous cilia on the surface of the respiratory membrane, which by their incessant action produce currents in their neighbourhood. In those aquatic animals, where the respiratory organ assumes the form of branched tubes or of cavities, the water in their interior is constantly undergoing a gradual renewal by the incessant action of the cilia upon the inner surface, and it is at other times expelled or renewed much more rapidly by the action of the surrounding contractile tissues. In some of the Crustacea where the branchiæ are lodged in a cavity placed under the lateral portions of the carapace, the renewal of the water is effected by the movements of distinct appendages, belonging more especially to the masticatory and locomotive organs; and in the Cephalopoda, where the branchiæ are placed in a cavity beneath the mantle into which the rectum and generative organs also open, the water is chiefly renewed by the contractions of the mantle. In fishes, whose demand for atmospheric air is greater, a complicated apparatus of muscles, bones, and nerves is arranged around the branchiæ, for keeping up a constant stream of water over the respiratory membrane. In insects the air in the tracheæ is chiefly renewed by the contractions and dilatations of the abdominal segments of the body.

In all the vertebrata that breathe by lungs, the muscles for renewing the air in contact with the respiratory surface are numerous, are called into action involuntarily and by excitations conveyed through the nervous system, and contract more or less frequently according to the wants of the organism. In batrachian reptiles, where the ribs are wanting, and in chelonian reptiles whose ribs are soldered together and immovable, the air is not drawn into the lungs, as in birds and the Mammalia, by the dilatations of the walls of the cavity enclosing them, but it is forced into the lungs chiefly by the action of the muscles attached to the hyoid bone as by a forcing-pump, from which it is again expelled chiefly by the abdominal muscles, as in the Mammalia and birds.*

The manner in which the nutritious juices are carried to and from the respiratory membrane is usually regarded as a part of the function of the circulation, and has already been described in the article on that function. The position and extent of the respiratory membrane, and the degree of activity required of it, are the circumstances that chiefly influence the arrangement of this portion of the circulatory apparatus, and the quantity and velocity with which the nutritious juices are circulated through it. When the respira-

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greater than that of the whole external surface of the body.

* In the Holothuria the tentacula appear to act as auxiliary respiratory organs. I have observed an active circulation of the nutritious juices in the tentacula of the Ocnus brunneus of Forbes.

* Detailed accounts of the respiratory organs in the different divisions of the animal kingdom are given in the articles under these heads. See also the article Palmo, supplement.

tory membrane is closely packed in a particular part of the organism, and the function of respiration is at the same time energetic as in the Mammalia, the blood is circulated with great activity, and in great quantity, through vessels distributed in this membrane, and appropriated solely to this purpose. When the respiratory membrane is extensively diffused, as in insects, throughout the organism, and the atmospheric air is brought into contact with it in the different tissues, a particular set of canals for carrying the nutritious juices to and from the respiratory membrane is not required; and were we, in such animals, to examine the circulatory apparatus without any reference to the nature of the respiratory apparatus, we could not understand how a circulatory apparatus, apparently so imperfect, is yet equally efficient in carrying on the nutritive processes as in other animals where its mechanism is much more complicated.

Apparatus for renewing the air in the lungs in the human species.— In man, as in the other Mammalia, this consists of three distinct parts: — 1st, of a movable framework composed of articulated bones and cartilages, but chiefly of the former, termed the thorax; 2dly, of muscles for enlarging and diminishing the capacity of the thorax; 3dly, of nerves through which the movements of these muscles are excited and regulated. The uses of this apparatus are not, however, restricted to respiration. The bones of the thorax furnish a certain degree of protection to the lungs, heart, and other important parts enclosed by them; and during certain violent efforts of the voluntary muscles, as in lifting a weight, they are no longer mobile as in the respiratory movements, but are rendered fixed, and afford a firm and steady *point d'appui* to the powerful muscles passing between the external surface of the thorax and the thoracic extremities, during their contraction. The same muscles which act involuntarily in dilating and contracting the chest in respiration, are frequently engaged in the performance of voluntary muscular movements, as in articulate speech, straining, &c. They also, in connexion with other muscles, or even alone, perform various involuntary muscular movements which are not respiratory, as in the excito-motory movements of coughing, sneezing, defecation, and urination, and in the sensational and emotional involuntary muscular movements of laughter, sighing, yawning, vomiting, &c.

The thorax can be enlarged in all its diameters by the action of its muscles, — in the vertical or atlanto-sacral, in the antero-posterior or vertebro-sternal, and in the transverse. Its enlargement in the antero-posterior and transverse directions is effected by the elevation of the ribs, and its enlargement in the vertical direction by the descent of the diaphragm, and by the elevation of the upper part of the thorax, but chiefly by the former. As the ribs in the human species differ in length, in the degree of their inclination to the spine, in the form and extent of their curvature, in the manner in which the anterior extremities of their cartilages of prolongation terminate, and in some other anatomical points which must influence their mode of action, the phenomena attending the elevation of the ribs are not the same over all parts of the chest, but it will be sufficient for our present purpose to state the general effects of these movements.* As the osseous arches formed by the ribs are so inclined upon the vertebral column that their lower edges form acute angles with that column, and their anterior or sternal are placed lower than their vertebral ends, and as their vertebral or posterior ends have a very limited extent of motion †, their elevation brings them to or near the horizontal plane, and carries forward their sternal extremities; and as the greater number of the ribs are attached to the sternum through their cartilages of prolongation, this bone must by this movement be pushed forwards, and the antero-posterior diameter of the thorax be enlarged.

The transverse diameter of the thorax is increased by the circumstance that the ribs during their elevation do not simply ascend, but perform a slight rotation round an axis passing between their anterior and posterior extremities, by which two effects are produced; 1st, their lower, which form a segment of a somewhat larger circle than their upper edges, are turned somewhat outwards, and the upper slightly inwards, so that the concavities of the arches formed by the ribs are now perpendicular, or nearly so, to the median plane of the body, instead of being oblique as before their elevation; 2dly, the middle portion of the greater number of ribs, which before was placed below a straight line passing through their two extremities, in consequence of the shaft of the rib bending upwards near the sternal end at what has been termed the anterior angle, is now placed on the same plane with the two extremities, and the whole rib rendered horizontal. This rotatory motion is greater at the middle of certain of the ribs as they rotate upon their two extremities, so that each rib in the performance of this movement may be considered as forming two levers, the two extremities being the pivots, and the middle of the ribs the ends of the levers most remote from the pivots.‡ The forward movement of the sternum is greater at its lower than at its upper part, in consequence of the greater length and inclination of the lower vertebro-sternal or true ribs, and the greater length of their cartilages, and the more acute

* Mr. Sibson has lately (Philos. Transact. of London, Part IV. for 1846, p. 528) given an elaborate analysis of the movements of the thorax in respiration. Dr. Hutchinson has also lately (Medico-Chirurgical Transactions of London, vol. xxix. 1846, p. 183) published some of the results of his observations on this subject.

† According to the observations of Haller (Element. Physiologiæ, tom. iii. p. 23. 1766) the greatest movement at the vertebral extremity of a rib is scarcely the one-sixth part of a line.

‡ These observations do not apply to the inferior ribs, especially the two last or floating ribs, as they are depressed in inspiration, and not elevated.

angles formed by their articulation with the sternum ; and this difference in the extent of movement in the two portions of the sternum must be still greater before the *manubrium* and the body of the bone are united by ossific matter.* Though this description of the movements of the sternum in respiration, which is that given by Haller†, has been called in question by some modern anatomists, there can be no doubt of its correctness, for it can be proved, by an appeal to the mechanism of the thorax, that, in the upward and forward movement of this bone, its upper and lower ends will pass through paths which differ considerably in their curvature and direction.‡ Though Haller was wrong in maintaining that the first rib is almost immovable in these actions of the thoracic walls, yet there can be as little doubt that Magendie is in error in asserting that this is the most movable of all the ribs ; for however favourable the nature of its vertebral articulation may be for motion, this is counteracted by the mode in which its cartilage of prolongation is united to the sternum.§

The position and form of the diaphragm is well adapted for enlarging, by its contraction, the vertical diameter of the thorax ; and being placed in the most capacious part of the thorax, even a slight elongation of the vertical diameter there will add considerably to the area of its inner surface. The convex or upper surface of the diaphragm, in its relaxed state, projects upwards on each side of its central or cordiform tendon into the thorax, and is higher anteriorly than posteriorly, and on the right side than on the left. This cordiform tendon is made a fixed point for the arched fibres that run from it to the ribs during their contraction, since it is pulled upon from below and behind by the two crura of the diaphragm, and in front by the short muscular fibres which pass to it from the point of the sternum and the lower edges of the cartilages of the ribs. If the lower ribs have been previously rendered steady by the action of the quadrati lumborum and serrati postici inferiores muscles, the arched muscular fibres of the diaphragm have another fixed point during their contraction. As the heart rests on the upper surface of the cordiform tendon, and the base of the lungs on the upper portion of the arched part of the diaphragm, the descent of the arched muscular fibres and their change to the horizontal position, causes a considerable enlargement of that part of the chest occupied by the lungs, while the position of the heart is comparatively little affected when the respiratory movements are moderate; but during forcible inspiration the heart recedes deeper into the chest, and during expiration it again comes forward.* The vertical diameter of the chest may be increased in inspiration by the pulling up of its superior portion, by the strong muscles of the neck attached to it, at a time when the lower portion is prevented from ascending, but an increase in the vertical diameter by an elongation of its upper part must have a much less effect in enlarging its capacity than an elongation of its lower part seeing that the thorax is at least four times as large at its lower as at its upper end. In ordinary respiration, and when the body is at rest, the ribs move little in the male, and the muscular movements of inspiration are chiefly carried on by the diaphragm.†

The ribs are elevated, in ordinary respiration, by the levatores costarum, external and internal intercostal muscles‡, and also, more

* During the elevation of the ribs the elastic cartilages of prolongation of the sternal ribs undergo a certain amount of torsion, and the angles they form with the sternum become less acute. The enlargement of the chest produced by the elevation of the ribs is greater in the antero-posterior than in the transverse diameter, and the enlargement in the transverse direction is much greater at the anterior than at the posterior portion of the chest, from the mode in which the ribs are articulated with the vertebral column.

† Haller (Mémoire sur plusieurs Phénomènes Importantes de la Respiration. Lausanne, 1758) found that the upper edge of the sternum was carried forwards $2\frac{1}{3}$, and the lower end from 3 to 8 lines, in a moderate inspiration.

‡ Ward's Human Osteology, p. 212. 1838.

§ The elasticity of the cartilaginous and osseous portions of the walls of the thorax will afford considerable resistance to the muscles in dilating it during inspiration. From the results obtained in two experiments upon the chest after death, Dr. Hutchinson calculates (Medico-Chirur. Transact. of London, vol. xxix. p. 205. 1846) that the force which the muscles of inspiration have to overcome in ordinary breathing from this source is probably, at least, equal to about 100 lbs., and in deep inspiration to about 300 lbs. In these calculations the additional resistance from the elasticity of the lungs was not taken into account.

* In the article Heart, Vol. II. p. 578, in stating this circumstance, the word inspiration was inadvertently used for expiration, and *vice versâ*.

† Dr. Hutchinson (Medico-Chirurg. Transact. of London, vol. xxix. p. 187. 1846) by a delicate instrument measured the costal movement during ordinary respiration in healthy individuals of the male sex, and found it not to exceed from two to four tenths of a line. The costal movements in the female sex, especially at the upper part of the chest, are considerably more extensive. Dr. Hutchinson states that the difference between the circumference of an ordinary man's chest measured over the nipples in the two states of a deep inspiration and a deep expiration, amounts to 3 inches (Opus cit. p. 222); and Valentin, under the same circumstances, found the average difference in the circumference of the chest, measured over the *scrobiculus cordis*, in seven individuals of the male sex between $17\frac{1}{2}$ and 33 years of age, to be 1 : 8·29 of the whole circumference. (Lehrbuch, &c. erster band, S. 541. 1844.) In old age, when the costal cartilages of prolongation become ossified, the mobility of the chest must be diminished.

‡ The mode of action of the intercostal muscles has been a subject of discussion since the time of Haller, — many entertaining the opinion of Haller, that both the internal and external sets act simultaneously as muscles of inspiration; some, that they are muscles of expiration; while others, again, assert that one set act during inspiration, and the other set during expiration. Those who maintain the last opinion are not agreed among themselves as to what set act as muscles of inspiration, and what as muscles of expiration. The mode of action of these muscles has lately been carefully examined by MM. Beau and Maissiat and Mr. Sibson (Opus cit.); and the two former (Archives Générales de Médecine, 4 série, tom. i. p. 268. 1843), conclude

especially in the female, by the scaleni muscles. When the respiration becomes hurried or more laboured, the diaphragm and the muscles that elevate the ribs not only act more vigorously in inspiration, but numerous other muscles, which may be termed auxiliary muscles of inspiration, act in unison with these.* In cases of great dyspnœa, as in a fit of asthma, the shoulders are fixed, the head is thrown back, and all the auxiliary muscles of inspiration are brought into violent action. When the shoulders are fixed by the action of the levatores anguli scapulæ, the rhombodei majores et minores, and the humeri also fixed by the scapulo-humeral muscles, or by the person grasping some fixed object by the hands, then the muscles, or portions of them which pass between the thoracic extremities and the anterior and lateral walls of the chest, as the serrati magni, the pectorales minores et majores, the subclavi, and perhaps the costal portion of the latissimi dorsi, act as muscles of inspiration, by pulling the ribs upwards and outwards†; and when the head, cervical vertebræ, hyoid bone, and larynx are fixed by the numerous muscles capable of performing this action, then the sterno-cleido-mastoidei, the sterno-hyoid, and sterno-thyroid muscles, may aid the scaleni muscles in drawing the superior part of the thorax upwards.‡ The serrati postici superiores, and the cervicales descendentes, are also accessory muscles of inspiration, if the former be not, at times, in fact a muscle of ordinary inspiration. The superior aperture of the larynx is dilated during inspiration by the crico-arytenoidei postici muscles when the breathing is in the least hurried; and in laboured breathing the nostrils are expanded by the contraction of the muscles, which draw the alæ of the nostrils outward. The greater or less demand for fresh air in the lungs regulates the number of these accessory respiratory muscles brought into play, and the energy of their contraction.

A diminution of the capacity of the thorax or an act of expiration, by which part of the air is expelled from the lungs, follows immediately each inspiratory movement. In ordinary respiration, after the muscles of inspiration have ceased to contract, the elasticity of the thoracic walls, especially of the cartilaginous portion, causes it to return to the state in which it was before its dilatation; and when the contracted diaphragm has relaxed, the elasticity of the parts displaced by its descent, is sufficient, without much, if any, aid from the abdominal muscles, to push the diaphragm again upwards. The gas present in greater or less quantity in the digestive tube, being compressed during the descent of the diaphragm, will, from its elasticity, assist in pushing upwards the relaxed diaphragm.* In more forcible expirations, when the walls of the chest are compressed beyond the state they assume when the muscles of inspiration are relaxed, the compressing muscles experience considerable resistance from the elasticity of the walls of the chest.

When the expirations are performed more forcibly than ordinarily, the diaphragm is pushed up, and the sternum and ribs depressed by the contractions of the three broad muscles of the abdomen, by the recti abdominis, and by the triangularis sterni muscles. The levator ani, one of the antagonist muscles of the diaphragm, assists also in pushing the abdominal viscera upwards. In hurried or laboured expirations the diaphragm is pushed more forcibly upwards by the muscles mentioned, and the ribs are pulled downwards, and the chest compressed, by the quadrati lumborum, serrati postici inferiores†, sacro-lumbales and longissimi dorsi muscles.

MM. Beau and Maissiat‡ have described three kinds of ordinary respiratory movements: 1. the abdominal, in which the abdominal walls chiefly act: 2. the costo-inferior, in which the movements chiefly take place in the lower ribs, from the seventh inclusive, downwards: 3. the costo-superior, in which the superior part of the chest is carried upwards by the elevation of the superior ribs and the sternum. The first kind, or the abdominal type, is observed in infants up to the end of the third year in both sexes; but after this period the costo-superior type in girls, and the costo-inferior and abdominal types in boys, generally prevail, and this difference becomes more marked as they advance in years. Almost all men, therefore, breathe by

that both sets are muscles of expiration, while the latter maintains the more probable opinion, that they act differently in different parts of the thorax. Dr. Hutchinson has also lately made some observations on the actions of these muscles in Medico-Chirurgical Transact. of London, vol. xxix. p. 213.

[Dr. Hutchinson regards the external intercostals and the intercostilaginous portion of the internal intercostals as muscles of inspiration, while the rest of the internal intercostals are muscles of expiration. See a further exposition of this author's views in the article THORAX. — ED.]

* According to Dr. Hutchinson (Opus cit. p. 187) the chief enlargement of the thoracic cavity in deep inspiration is made by the ribs, and *not* by the diaphragm.

† Part of the muscles passing between the thoracic extremities and the anterior and lateral walls of the chest, here enumerated among the accessory muscles of inspiration, may, in certain cases, act as accessory muscles of expiration, by drawing the scapulæ forcibly downwards upon the ribs. (Vide observations of Mr. Sibson and MM. Beau and Maissiat.) These authors are not of the same opinion regarding the action of all these muscles; for, while the two former class the serratus magnus among the muscles of inspiration (Opus cit. tom. iii. p. 268. 1843), the latter affirms that the greater portion of its fasciculi acts visibly in violent expiration (Opus cit. p. 535): they agree, however, in placing the latissimus dorsi among the accessory muscles of expiration.

‡ The hyoid bone, larynx, and trachea are sometimes drawn downwards during violent inspirations by the strong contractions of the sterno-hyoid and sterno-thyroid muscles, causing a depression of these parts, at the same time that they elevate the sternum.

* Maissiat, in his Etudes de Physique Animale, and Beau and Maissiat in Arch. Génér. de Méd. tom. iii. p. 263. 1843.

† Dr. Hutchinson informs us that the body is considerably shortened during violent expiration. (Op. cit. pp. 191, 192.)

‡ Archiv. Gén. de Méd. tom. xv. p. 399. 1842.

the lower part, and women by the upper part of their chest, and this independently of the effects of particular articles of dress! * This difference in the mode of respiration in the two sexes is, in general, maintained even in dyspnœa, unless it be very severe. As the costo-inferior and abdominal types of respiration would be impeded in the female when pregnant, the ordinary costo-superior type of respiration in the female has apparently a reference to that condition.†

Valentin‡, Dr. Hutchinson§, and Mendelssohn ||, have lately made experiments upon the force of the muscular movements of inspiration and expiration. Those of Dr. Hutchinson are much the most extensive, and are 1500 in number. He found that the power of expiration is nearly one third stronger than that of inspiration; and he states that whenever the expiratory are not stronger than the inspiratory muscles, that some disease is present. He tested the force of the two classes of respiratory muscles by causing persons to make the most powerful efforts of which they were capable when breathing through the nose into an instrument constructed for the purpose, and the subjects of experiment were taken from individuals of the male sex, following very different occupations. In examining the results of the whole experiments, and including all the thirteen classes of men subjected to experiment, the power of the inspiratory muscles is found greatest in men of 5 feet 9 inches in height, their inspiratory power being equal, on an average, to a column of 2·75, and their expiratory power to 3·97 inches of mercury; while in four of these classes, composed generally of active, efficient, and healthy individuals, viz. Firemen, Metropolitan Police, Thames Police, and Royal Horse Guards, the inspiratory power of the men of 5 feet 7 inches was the greatest, being equal to 3·07 inches of mercury, and those of 5 feet 8 inches to 2·96 (nearly 3 inches). The average power of the 5 feet 7 inches and 5 feet 8 inches men of all the thirteen classes was only 2·65 inches of mercury. The inspiratory power of twelve six-feet men in the first battalion of Grenadier Guards was only 1·92 inches, while that of thirty-one of the same height in the Blues (Life Guards) was 2·71 inches. He infers from these experiments that a healthy man of 5 feet 7 inches or 5 feet 8 inches, should elevate by inspiration 3 inches of mercury. The force of the expiratory muscles is more liable to be affected by the ordinary occupation of the individual than that of the inspiratory muscles, and therefore the state of the former is less to be relied upon in judging of the health of the individual than that of the latter.* The elasticity of the walls of the chest is, no doubt, one cause of the greater force of the expiratory over that of the inspiratory muscles.

In inspiration the pressure of the elastic air in the lungs causes these organs to expand, so as to keep their outer surface in contact with the inner surface of the dilating thorax; and by this the air of the lungs becomes rarified, and a quantity of fresh air rushes along the trachea and bronchial tubes to restore its equilibrium; in expiration, on the other hand, the lungs are compressed, and a portion of air is forced outward along the same passages. In these movements the lungs are not quite passive. The external surface of the lungs, and of the numerous lobes into which they may be divided, is covered with an elastic membrane, and this, conjoined with the weight of their tissues, must favour the expulsion of the air during expiration, and present a certain amount of resistance to its entrance during inspiration.†

* These observations of Beau and Maissiat upon the differences in the respiratory movements in males and females are confirmed by Dr. Hutchinson (Op. cit. p. 195), and they were known so far to Boerhaave and Haller.

† These authors also state that this difference in the respiratory movements of the two sexes have impressed upon the chest certain anatomical differences; for while the intercostal spaces at the upper part of the chest are larger in the female, those at the lower part are larger in the male; and while the first rib is movable in the female, it is almost or entirely immovable in the male.

‡ Lehrbuch der Physiologie des Menchen, band i. S. 524. 1844.

§ Journal of the Statistical Society of London, vol. vii. p. 193. 1844; and Medico-Chirurg. Transactions of London, vol. xxix. p. 197. 1846.

|| Der Mechanismus der Respiration und Circulation, S. 116—120. Berlin, 1845.

* Valentin's experiments upon the respiratory forces were performed upon six males between 18 and 32 years of age. In ordinary tranquil respiration the force of each of the acts of inspiration and expiration was equal to the weight of a column of mercury of from 4 to 10 millimetres (or from ·1574 to ·3937 of an English inch); in the least forcible respiration it ranged between 20, 35, and 40 millimetres of mercury (from ·7874, 1·377, and 1·5748 of an English inch). In ordinary tranquil respiration in the same individual, at different periods, the range of the respiratory force was even more than between 5 and 10 millimetres (or between ·1968 and ·3937 of an inch). The average force of an ordinary tranquil respiration, when the nose was held and the individual inspired and expired through the mouth, was 6·45 mill. (·2539 of an inch); when they inspired through the nose and expired through the mouth alone, it was 10·6 mill. (·4173 of an inch); and when they inspired through the nose and expired through the nose and mouth, it was 5 mill. (·1968 of an inch), or about one half of the strength when they expired through the mouth alone. He found that the strongest inspiration of which these individuals were capable was equal to 144·3 mill. (5·6812 inches) of mercury, and the strongest expiration to 204 mill. (8·0316 inches) of mercury. Mendelssohn's experiments were performed upon seven individuals, and they breathed through one nostril, the other nostril and the mouth being shut. He found that the force of the most powerful expiration was greater than that of the most powerful inspiration by about one inch of mercury. The most powerful expirations were on an average between 4·4 and 4·8 inches of mercury. In performing such experiments it is necessary to breathe through the nose, the mouth being shut, as in those of Dr. Hutchinson and Mendelssohn, if we wish to obtain the force of the muscles of the chest, apart from that of those of the cheeks.

† Dr. Carson (Philos. Trans. of London for 1820, p. 42), states that in his experiments on "calves,

When the external air is admitted freely into the sac of the pleura, by an opening in the parietes of the thorax sufficiently large to permit the air to pass through it in greater quantities than it can enter the lungs by the trachea, the lung collapses rapidly and is compressed against the spine; and if this take place on both sides of the chest, the respiratory process is arrested, and the individual dies, as from suffocation. When the lungs lose their elasticity, and the air-cells become dilated and their septa partially broken down, as in emphysema, the respiratory membrane is not only diminished in extent, but expiration is more difficult, and when the chest is laid open after death, the lungs collapse imperfectly or not at all. It is evident that still more serious evils must follow interlobular emphysema, or effusion of air into the cellular tissue surrounding the smaller lobes of the lungs, if this occurs to a considerable extent.

Though the trachea, the bronchii, and even the smaller bronchial tubes are provided with distinct muscular fibres which can be thrown into contraction by direct excitation, and even, according to some experimenters, by excitation of their nerves, yet the notion entertained by many of the older, and even by some modern physiologists, that the lungs have an active power of contraction and dilatation synchronous with and aiding the movements of inspiration and expiration, is undoubtedly untenable. These muscular fibres of the bronchial tubes are endowed with that kind of contractility termed *simple contractility*, which manifests itself by more slow and prolonged contractions and relaxations than that of the voluntary muscles and the heart.* The possession of this property of simple contractility unfits these muscular fibres from acting simultaneously with the muscles of respiration moving the thorax, but fits them for effecting these changes on the capacity of the air-tubes, which may aid in the expulsion of substances from their interior, as in coughing. The movements of the cilia placed on the inner surface of the respiratory organs, can assist little, if at all, in renewing the atmospheric air in the lungs. The passage of the air into and from the lung, has an important effect upon the muscular respiratory movements. When a lung, or a considerable portion of it, is prevented from expanding by disease or any other cause, the pressure of the air on the inner surface of that portion of the chest covering the unexpansible lung is not now exercised during its dilatation; in other words, this portion of the chest in expanding must do so in opposition to the whole of the atmospheric pressure on its outer surface, amounting to 15 pounds on the square inch. This pressure appears to be too great for the muscles of inspiration, acting upon that part of the chest, to overcome, for the ribs are there motionless or nearly so, and if the lung is in a state of collapse, the walls of the thorax covering it fall in.

The muscular movements of inspiration and expiration are, in the natural and healthy state of the body, performed without the intervention of volition, and even without our consciousness, and belong to the class of movements which have lately received the appellation of excito-motary. When, however, the free aeration of the blood in the lungs is impeded, a sensation, urgent and imperious in its demands, is felt, which in our language is somewhat clumsily designated "the sensation of the want of fresh air in the lungs," and more elegantly in French, *le besoin de respirer*. These respiratory movements, therefore, depend upon the transmission inwards of certain excitations along afferent nerves to the central organs of the nervous system, whence a motive influence is sent outwards along the motor or efferent nerves distributed in the muscles to be moved. One of the principal excitor or afferent nerves of respiration is the par vagum; and the medulla oblongata is the portion of the central organs of the nervous system to which all the excitations of the nervous system capable of producing a respiratory muscular movement must be brought. The motor or efferent nerves that convey outwards from the medulla oblongata the motive influence which stimulates the muscles of respiration to contract are the phrenic, and part of the anterior roots of the dorsal and lumbar spinal nerves, the recurrent laryngeal, the portio dura, the spinal accessory, and some branches of the cervical and upper part of the axillary plexus besides the phrenic, especially the branch distributed in the serratus magnus muscle, termed by Sir Charles Bell the *external respiratory*. Some of these efferent nerves, like the muscles in which they are distributed, are habitually engaged in carrying on the respiratory muscular movements, while others aid these only when the respiration requires to be carried on more vigorously than usual.

We have already pointed out the extent to which the nervus vagus acts in conveying to the central organs of the nervous system those impressions that excite the *besoin de respirer* and the muscular movements of inspiration. (*Vide* art. PAR VAGUM.)

It is impossible to determine whether or not the pulmonary ganglionic nerves can convey inwards to the central organs of the nervous system impressions capable of exciting the respiratory muscular movements; but that impressions capable of exciting such movements to a certain extent may be re-

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sheep, and large dogs, the resiliency of the lungs was found to be balanced by a column of water varying in height from one foot to a foot and a half, and in rabbits and cats by a column of water varying in height from six to ten inches." Vide also Observations by M. P. Berard on the Effects of the Elasticity of the Lungs, in Archives Génér. de Médecine, tom. xxii. p. 180. 1830.

* Vide experiments of Wedemeyer (Untersuchungen über den Kreislauf, p. 70), and of Dr. C. J. B. Williams (Transact. of British Scient. Assoc. for 1840, p. 411), upon the contractility of the bronchial tubes.

ceived by other nerves than those distributed in the lungs, is proved by the fact, which we have witnessed, that a few distinct respiratory movements may be observed in an animal after its lungs have been removed. That portions of the posterior roots of the spinal nerves distributed in the external cutaneous surface do act as excitors of respiration under certain circumstances, is proved by the effects of dashing cold water on the surface of the body, especially on the face. It is also probable that the circulation of venous blood in the arteries of the medulla oblongata may also cause the transmission of the motive influence outwards to the respiratory muscles. What are the excitations which lead to the performance of the muscular movements of expiration? Do the same excitations that occasion the muscular movements of inspiration, operate in the production of the expiration which immediately follows, so that they are to be considered two stages of the one and the same muscular action? These are questions which we are not prepared to answer. When the functions of the medulla oblongata are arrested, the motive influence of volition cannot pass downwards from the encephalon to the motor nerves that move the chest in respiration; and as all the excited or involuntary movements of respiration of the same muscles must, for the reasons already stated, instantly cease, immediate death is the consequence. Destruction of a portion of the spinal chord below the medulla oblongata and above the origin of the phrenic nerve will also produce the same result, for though the excitations that lead to the performance of the respiratory muscular movements reach the medulla oblongata, the motive influence cannot pass downwards to reach the motor nerves distributed in the muscles which act on the thorax.

Frequency of the respiratory muscular movements. — The frequency of the respirations varies in different individuals, and at different ages, and is so much influenced by the condition of the body and the mind at the time, even when the individual is in perfect health, that it is a much more difficult matter to determine their average frequency than may at first be imagined. Quetelet* has constructed the following table on the frequency of the respirations, at different ages, per minute, from observations made on 300 individuals.

	Inspirations.		
	Average.	Max.	Min.
At birth	44	70	23
5 years	26	32	
15—20	20	24	16
20—25	18·7	24	14
25—30	16	21	15
30—50	18·1	23	11

* Sur l'Homme et le Développement de ses Facultés, &c. tom. ii. p. 91. Bruxelles, 1836.

Mr. Hutchinson* gives the following table of the number of respirations per minute in adults when in the sitting posture, in 1714 adults of the male sex, considered to be in a state of health.

Number of Respirations per Minute.	Number of Cases.	Number of Respirations per Minute.	Number of Cases.
6	1	26	8
9	1	27	2
10	2	28	30
11	1	29	2
12	19	30	6
13	10	31	0
14	21	32	6
15	12	33	0
16	216	34	1
17	95	35	0
18	181	36	1
19	70	37	0
20	510	38	0
21	120	39	1
22	136	41	1
23	41		
24	220	Total	1714
25	16		

From Mr. Hutchinson's table it would appear that the majority of male adults breathe between 16 and 24 times per minute, and that of these a great number make 20 respirations per minute.†

According to Prevost and Dumas‡, the ratio of the respirations to the pulsations of the heart is as 1 to 4. According to Mr. Hutchinson§, "the prevailing numbers run as four beats of the heart to one respiration." Quetelet|| states, that "it does not appear that there is

* Medico-Chirurgical Transactions of London, vol. xxix. p. 226. 1846.

† The following results upon the frequency of the respiration in a state of rest have been obtained by others; but as these were made upon their *own persons*, they possess only the value of individual cases. Dalton (Memoirs of the Literary and Philosophical Society of Manchester, 2nd series, vol. ii. p. 26, 1813) found the number of his respirations to be 20 per minute; Thomson (System of Chemistry, vol. iv. p. 604, 1820), to be 19; Sir H. Davy (Researches chiefly concerning Nitrous Oxide and its Respiration, p. 434, 1800), to be 26 or 27; Magendie (Compendium of Physiology, translated by Milligen, p. 390, 1831), to be 15; Dunglisson (Human Physiology, vol. ii.), to be 16; and Allen and Pepys, on one of themselves (Philos. Trans. of London for 1808), to be 19. Menzies (Teutamen Physiol. Inaug. de Respiratione, 1790), found them to be 14 in the minute in the person on whom he experimented; Vierordt (Article "Respiration" in Wagner's Handwörterbuch der Physiologie, band ii. S. 834), in his own person, found them on an average to be $11\frac{9}{10}$ when sitting, and the mind disengaged; while their maximum was 15, and their minimum 9. Dr. Guy (Hooper's Vade-Mecum, edited by Dr. Guy) ascertained that the respirations in his own person were 22 in a minute while standing, 19 when sitting, and 13 when in the recumbent position.

‡ Vide Burdach's Traité de Physiologie, traduit de l'Allemand par Jourdan, tom. vii. p. 38. 1837.

§ Journal of the Statistical Society of London, vol. vii. p. 205.

|| Op. cit.

a determinate ratio between the pulsations and respirations; however, in many individuals, and I am of the number, it is as 1 to 4." Dr. C. Hooker* informs us that, from numerous careful observations, he has arrived at the conclusion, that the numerical relation between the beats of the heart and the respirations (except in infancy) is as 1 to 4½, and that any marked deviation from this relation indicates some mechanical or structural impediment to the free play of the lungs. According to Burdach†, the same circumstances which diminish the frequency of one of these movements acts equally upon the other; but it is proved by the recent observations of Dr. Guy, that these variations do not bear the same proportion to each other. In Dr. Guy's experiments‡, the proportion between the respirations and the pulse has varied from 1 : 2·60 to 1 : 5·23; and whereas the pulse becomes less frequent as the day advances, the respiration increases in frequency, so that there are 18 respirations in the evening for 17 in the morning. The chief cause of the variation in the ratio of the respirations and the pulse "is the position of the body. Thus, for a pulse of 64, the proportion standing was 1 : 2·95; sitting, 1 : 3·35; and lying, 1 : 4·97. In the sitting posture, but from different frequencies of the pulse, it has varied from 1 : 2·61 to 1 : 5·00. The proportions morning and evening for the same frequency of the pulse are about 1 : 3·60 and 1 : 3·40. The proportions which the respiration bears to the pulse decreases as the pulse increases. Thus, for a pulse of 54 the proportion was 1 : 3, for a pulse of 72 it was 1 : 4."

Quantity of air drawn into the lungs at each inspiration, and expelled at each expiration; and the quantity of air in the lungs at different times. — During ordinary respiration in a state of health, and when the body is at rest, a small quantity only of the air which the lungs can contain is exchanged by each act of inspiration and expiration. The average amount of air in the lungs in the state of ordinary respiration, may be considerably increased or diminished by forced inspirations and expirations, but the whole air contained in the lungs cannot be expelled by the most powerful action of the muscles of expiration. The quantity of air drawn into the lungs by each inspiration and again expelled by expiration, in the state of ordinary respiration, not only varies in different individuals, but in the same individual in different conditions of the body, so that the results obtained by physiologists on this point must necessarily be dissimilar, and the more especially as the greater number of these have experimented only upon a single, or a very limited number of individuals. The difficulty of ascertaining the average quantity of air exhaled at an ordinary expiration, and the great range that occurs in this respect, may be judged of by the statement of Vierordt, that the variation in his own person is as great as 1 : 4·75.* The probable average quantity of air drawn into the lungs at each inspiration even in healthy individuals, at different ages and in different states of the body and of the physical conditions under which it may be placed, can only be ascertained by the performance of a much more extended series of experiments than we at present possess; and the ascertainment of the causes which determine these variations from the average quantity will be still more difficult, and of still more importance. All such experiments are liable to many sources of fallacy, both from imperfections in the instruments used in conducting them, and from the muscular movements of respiration being unwittingly influenced by the attention of the persons experimented upon being fixed upon these movements; but the later experiments on this point are more trust-worthy than the earlier, as the instruments employed are better suited for the purpose, and by frequently repeating the experiment on the same persons, they at last become accustomed to the artificial circumstances under which they are placed, and they breathe more naturally.

Herbst, from his experiments, concluded, that a healthy adult of average size should in an ordinary inspiration inhale from 20 to 25 Parisian cubic inches (24·211 to 30·263 English cubic inches), and exhale the same quantity in expiration; while an individual of a feebler constitution of body should inhale from 16 to 18 Parisian cubic inches (19·368 to 21·789 English cubic inches).† Valentin gives as the result of his experiments upon seven males between 17½ and 33 years of age, that the quantity of air expired in ordinary up to a somewhat quickened respiration, ranges between 239·3 and 1567·7 cubic centimetres (14·603 and 95·672 English cubic inches), the average of which was 655·11 c.c. (40·081 English cubic inches).‡ Vierordt§, in repeated experiments upon himself, ascertained that at each expiration, when in a state of rest, he expelled from the lungs on an average 507 cubic centimetres (30·940 English cubic inches), and that the average of the five highest values was 699 c.c. (42·657 E.c. inches), and of the lowest 177 c.c. (10·801 E.c. inches).‖ Bourgery, from experiments upon

* Boston Medical and Surgical Journal for 1838. Vide also British and Foreign Medical Review, vol. vii. p. 263.

† Op. cit. p. 39.

‡ Hooper's Vade-Mecum, edited by Dr. Guy, pp. 131, 132. 1846.

* Wagner's Handwörterbuch der Physiologie, band ii. s. 836.

† Meckel's Archiv für Anatomie und Physiologie, band xiii. S. 83. 1828.

‡ Lehrbuch der Physiologie, band i. S. 538. These calculations of Valentin rest on the supposition that the expired air is *fully* saturated with moisture — a supposition invalidated by the experiments of Moleschott.

§ Wagner's Handwörterbuch der Physiologie, band ii. S. 835. Vierordt elsewhere states that he is of the middle height, and has no particularly roomy chest, was 59 kilogrammes in weight and 25 years of age when he performed his experiments.

‖ The following estimates have been drawn from a limited number of experiments upon a single individual, or upon a very small number of in-

fifty males and twenty females*, with the view of ascertaining the relation between the intimate anatomical structure of the lungs, and the functional capacity of these organs in the two sexes, concludes that the volume of air required by an individual in ordinary respiration augments gradually with the age, being least in youth (from 5 to 15 years), in consequence of the extreme vascularity of the lungs; increased from 15 to 30 years of age, in consequence of the proportional diminution in the closeness of the pulmonary capillary network of blood vessels; and to a much greater amount in old age, in consequence of the more rapid diminution of the extent of the respiratory membrane, which begins to take place after the lungs have arrived at their full development, or the age of 30.

It is obvious that we are not yet in possession of data to enable us to venture upon an estimate of the *average* quantity of air inspired and expired at an ordinary respiration, when the body is at rest and the mind undisturbed, at different periods of life, in the two sexes, and in different physical configurations of body. It is equally apparent that this is liable to considerable variation, and that the different results obtained by most experimenters, — setting aside those where an obviously faulty method was pursued, — depends as much upon the inherent differences in the extent of the respiratory movements in the individuals experimented upon, as upon errors in the mode of experimenting, and that the chief error committed by some of them consists in deducing averages from the few and insufficient experiments performed by themselves, and casting doubts upon the results obtained by others, simply because they do not accord with their own. It also necessarily follows that we are not in a position to form an estimate of the *average* quantity of air which passes out and in from the lungs in twenty-four hours in ordinary respiration. Vierordt*, from experiments on his own person, calculates that he respires 6034 cub. cent. (368·074 English c. inches) of atmospheric air in one minute, or 8,688,960 cub. cent. (530,026·560 Eng. c. in.) in the twenty-four hours. As, however, the respiration is rendered more energetic by speaking, walking, &c., any estimate drawn, as this by Vierordt is, from observations made when the body was in a state of rest, will be, as he was aware, too low; and proceeding on some of the results of Scharling's experiments, he makes allowances for this increase, and estimates the quantity of air respired in the twenty-four hours at 624,087·401 English cubic inches. Valentin † calculates that in his own person, after making allowances for temperature and watery vapour, he respires 469·9755 litres (28681·1948 English cubic inches) in an hour, and 688,348·6761 Eng. cubic inches, or nearly 398½ cubic feet of atmospheric air in the twenty-four hours.‡

The quantity of air drawn into the lungs during *quickened* or *forced* inspiration, and again expelled during expiration, also varies very considerably in different individuals of the same age. Sir H. Davy §, in many experiments upon himself, ascertained that at a temperature from 58° to 62° Fahr. he threw out of his lungs by a full forced expiration,

	Cubic Inches.
After a full voluntary inspiration, from	189 to 191
After a natural inspiration, from	78 — 79
After a natural expiration, from	67 — 68

So that, making corrections for temperature, he calculates that his lungs, in a state of voluntary or forced inspiration, contained about 254 cubic inches; in a state of natural in-

dividuals, and are therefore of little value in enabling us to ascertain the *average* quantity of air taken into the lungs and again expelled in ordinary respiration. Besides, some of these experiments are liable to obvious objections. Borelli (De Motu Animalium, Pars Secunda, p. 118. Lugdani, 1685) who appears to have been the first who attempted to ascertain this by experiment, estimates it at 15 cubic inches. Turin (Diss. p. 41, 42, as quoted by Haller), from experiments on his own person, at 40 cubic inches; and this is the estimate also formed by Menzies (op. cit. p. 28,) from his experiments. Goodwyn (The Connexion of Life with Respiration, &c., p. 36. 1788), from experiments on three individuals, estimates the quantity inspired at 12 cubic inches, which he supposes to be increased to 14 in the lungs by the increase of temperature. Sir H. Davy (Researches Chemical and Philosophical, &c., p. 433, 1800) informs us that he threw out of his lungs at each ordinary inspiration nearly 13 cubic inches; Mr. Abernethy (Surgical and Physiological Essays, Part II. p. 142, 1793), that he inspired 12 cubic inches; Dalton (Memoirs of the Literary and Philosophical Society of Manchester, 2nd Series, vol. ii. p. 26), also from experiments on his own person, estimates an ordinary inspiration at 30 cubic inches; Allen and Pepys (London Phil. Trans. for 1808), from experiments on one individual, at 16½ cubic inches; and Thomson (Animal Chemistry, p. 612. 1843) estimates his own inspirations at 16 cubic inches.

* Archiv. Général. de Méd. 4ᵉ Série, tom. i. p. 375, 1843, and Comptes Rendus, 23 Janvier, p. 182. 1843.

* Op. cit. pp. 856, 857.

† Op. cit. p. 570. The effects of exercise, digestion, &c., are included in this estimate.

‡ Mr. Coathupe (London and Edinburgh Phil. Magaz. vol. xiv. p. 401, 1839), from experiments on his own person in a state of rest, estimates the number of respirations at 20 in the minute, the average bulk of each respiration at 16 cubic inches, and the quantity of air that passes through the lungs in 24 hours, at 460,800 cubic inches, or 266·66 cubic feet. Mr. Coathupe's estimate agrees pretty closely with that of Dumas (Statique Chimique des Etres Organisés, 3ᵉ edit. p. 87), also formed from experiments on his own person, in a state of rest.

The estimate of the quantity of air that passes through the lungs, given by Bostock (System of Physiology, p. 321, 1836) is in all probability above the average. He proceeds on the supposition that in ordinary respiration a man respires 40 cubic inches of air 20 times in a minute, so that he makes the quantity respired in the 24 hours, 1,152,000 cubic inches or about 666½ cubic feet. It is probable that between 25 and 30 cubic inches of air for each ordinary inspiration will be found to be near the average in an adult male when in a state of rest.

§ Researches Chemical and Philosophical, &c., p. 410. 1800.

spiration about 135; in a state of natural expiration about 118; and in a state of forced expiration 41.* Goodwyn†, in his experiments on the capacity of the lungs upon four individuals after a natural death, found the residual air in the lungs to vary from 90 to 125 cubic inches, giving an average of 109, and as the chest, after a natural death, may be regarded as in a state of natural or ordinary expiration, this result differs very little from that of Davy. Allen and Pepys ‡, in one experiment on the capacity of the lungs in a middle-sized man after death, also obtained a little more than 100 cubic inches of residual air. Vierordt § supposes that the residual air in the lungs, after the *deepest* expiration, is about 600 cub. cent. (36·600 Eng. cub. in.), which differs but little from the estimate of Davy.

Herbst ‖ made experiments upon 11 males, between 16 and 30 years of age, with the view of ascertaining the quantity of air drawn into the lungs in forced inspiration. The smallest quantity observed was in a Jew aged 22, of small stature, and feeble muscular system. He inspired between 60 and 70 Parisian cubic inches (between 72·635 and 84·738 Eng. cub. in.) after an ordinary expiration; between 102 and 118 (123·476 and 142·844 Eng. cub. in.) after a strong expiration; and 120 (145·266 Eng. cub. in.) after the strongest expiration. The largest quantity inspired was by a young man of 25 years, of middle height with a broad chest and large and powerful muscles, who inspired by a forced inspiration, about 169½ English cubic inches, without any previous voluntary expiration; about 290½ after a strong expiration; and about 290½ or 295⅓ after the strongest expiration. A young man of 23 years of age, 6 feet high, with broad chest and large muscles, inspired, without any previous voluntary expiration, 121 English cubic inches, and 280·72 after the fullest expiration. The quantities of air drawn into the lungs in forced inspiration in the other eight males, were intermediate between the highest and lowest mentioned above, and the average was about 202 English cubic inches.¶ Herbst also satisfied himself that the lungs of females have a considerably smaller capacity for air than those of males. He states that robust females, about the age of 30, may inspire without a previous voluntary expiration, 72½ English cubic inches, after an ordinary expiration nearly 109, and after the strongest expiration, from about 157⅓ to 174⅓ English cubic inches.* Herbst had an opportunity, in two of these experiments on males, of ascertaining the effects of tight clothing on the extent of the respiratory movements. One individual who inspired 128 and another 116·16 English cubic inches, without a previous expiration after the clothes were loosened, could before this only inspire 96·80 and 60½ English cubic inches. † The most extensive experiments by far, made with the view of ascertaining the quantity of air which can be thrown out of the lungs by forced expiration, after the deepest inspiration, are those of Mr. Hutchinson. ‡ These experiments were performed upon 1923 males, and they were made to breathe into an instrument constructed for the purpose, and which he has called a *spirometer*. He has inferred from the data he has collected on this point, the rule, that "for every inch of height (from 5 feet to 6) 8 additional cubic inches of air at 60° Fahr. are given out by a forced expiration;" so that he believes that from the height alone of an adult male, he can tell what *quantity* of air he should breathe to constitute him healthy, and that this method may be turned to important practical application in ascertaining disease of the lungs,

* Sir H. Davy states that this capacity is most probably below the medium, as his chest was narrow.

† Op. cit. p. 26.

‡ Philos. Trans. of London, 1809.

§ Op. cit. p. 892.

‖ Op. cit. p. 98.

¶ Herbst found that a boy of 15 years inspired 116·16 English cubic inches after a strong expiration, and expired the same quantity after a full inspiration. Another boy of 13 years, but of the size of one of 15, likewise expired 116·16, while a boy of 11 years inspired without a previous expiration, 36·30; after a strong expiration he inspired 72·60 English cubic inches, and expired the same quantity after a full inspiration.

* Bourgery (op. cit.) states, that in well formed and healthy individuals, a man at 30 will, by a forced inspiration, draw into the lungs 2·50 to 4·30 litres (or 152·567 to 262·416 English cubic inches), and a woman from 1·10 to 2·20 litres (or 67·129 to 134·259 English cubic inches), and has inferred from his experiments, that at the same age the amount of forced respiration of the male doubles that of the female, and this conclusion accords with the results of Mr. Thackrah (The Effects of Arts, Trades, and Professions, &c., on Health and Longevity, 2nd edit. p. 181, 1832), who states that "extensive examination shows us that, while healthy men exhale by the pulmometer 200 cubic inches and upwards, women rarely exceed 100, and often do not reach that amount." Mr. Thackrah supposes that this difference is due, to a considerable extent, to tight lacing by females.

† The condition of the stomach as to fulness, also affects the extent of the respiratory muscular movements. Mr. Hutchinson says, "I have found a dinner diminish the vital capacity (by which he means the greatest voluntary expiration following the deepest inspiration) to the extent of 12 and even 20 cubic inches." The position of the body has also, according to Mr. Hutchinson (opus cit. p. 197), a considerable effect upon the vital capacity of the chest. In experiments upon himself he found that when standing he could throw out 260 cubic inches; sitting, 255; and when recumbent (supine), 230, (prone) 220, so that position effected a difference of 40 cubic inches. In a fit of dyspnœa a person can breathe easier in the erect or sitting than in the recumbent posture, as the dorsal movements that attend difficult respiration, are freer in the former than in the latter position.

‡ Journal of the Statistical Society of London, vol. vii. 1844, and Medico-Chirurgical Transactions of London, vol. xxix. p. 137. 1846. The memoir in the last publication contains a more extensive series of experiments than that in the former. These researches would require to be still farther extended upon both sexes at the various periods of life, and under varied circumstances, before they can yield all the information on this subject that is desirable.

under circumstances where the ordinary methods fail. Mr. Hutchinson has given the following table to show the quantity of air expelled by the strongest expiration after the deepest inspiration for every inch of height between 5 and 6 feet, as ascertained by actual experiment (column 1) by his *spirometer*, and as calculated according to the rule mentioned above (column 2).

Height.	From Observation.	Regular Progression.
ft. in. ft. in.	cub. in.	cub. in.
5 0 to 5 1	174	174
5 1 — 5 2	177	182
5 2 — 5 3	189	190
5 3 — 5 4	193	198
5 4 — 5 5	201	206
5 5 — 5 6	214	214
5 6 — 5 7	229	222
5 7 — 5 8	228	230
5 8 — 5 9	237	238
5 9 — 5 10	246	246
5 10 — 5 11	247	254
5 11 — 6 0	259	262*

Mr. Hutchinson has found that two other conditions of the body besides the height, regulate the quantity of air that passes to and from the lungs in forced voluntary respiration, and these are age and weight. He states that weight does not affect the respiratory power of an individual of any height between 5 feet 1 inch and 5 feet 11 inches until it has increased 7 per cent. above the average weight of the body in persons of that height, but beyond this it diminishes in the relation of 1 cubic inch per pound for the next 35 pounds—the limit of the calculation. In males of the same height the respiratory power is increased from 15 up to 35 years of age, but from 35 to 65 years it decreases nearly $1\frac{1}{2}$ cubic inch for each year.† Bourgery concludes from his experiments already referred to, that the measure of respiration (by which he apparently means the quantity of air which may be drawn into the lungs by a forced inspiration) is greater the younger and thinner the person is; that its maximum in both sexes occurs at the age of 30; that the relation of a forced and ordinary respiration diminishes with the age of the individual, being, he says, from 1 to 12 at three years of age, as 1 to 10 at fifteen, as 1 to 9 at twenty, as 1 to 3 at sixty, and as 1 to $\frac{1}{2}$ or $\frac{1}{3}$ at eighty years; whence it follows that in youth there is an immense respiratory power in reserve for any violent exertion, while in old age the individual under such circumstances is at once out of breath.*

Changes upon the atmospheric air in respiration.— One of the most obvious changes, under ordinary circumstances, upon the air that enters the lungs in respiration is an increase of its temperature, and consequently an augmentation of its bulk. As a quantity of water is readily supplied by the fluid secretions of the inner surface of the air-passages, and by the blood in the pulmonary capillary blood-vessels, this augmentation of the temperature of the air is also necessarily attended by an increase of its watery vapour, and consequently by an additional increase in its bulk and elasticity. The expired air, therefore, contains more caloric, more watery vapour, is more elastic, and is of less specific gravity than the inspired air. Valentin performed 12 experiments on his own person by breathing through an apparatus invented by Brunner and himself, to ascertain the temperature of the expired air, and he obtained the following results. In breathing atmospheric air of a temperature varying from 8°·5 to 33°·5 Reaumur (51°·125 to 107°·375 Fah.), he observed a difference of 1°·75 R. (3°·937 F.) in the temperature of the expired air. While breathing in the lowest temperature, viz. 51°·125 F., the temperature of the expired air was 96°·687 F., and was warmer than the inspired air by 45°·562 F.; and when breathing in the highest temperature the expired was colder

* Med.-Chir. Trans. vol. xxix. p. 237. Experiments to ascertain the quantity of air that may be inspired or expired in forced respiration have also been performed by Hales (Statical Essays, vol. i. p. 243), Jurin, Menzies, Goodwyn, Dr. Bostock (System of Physiology, p. 316. 1836), Dalton (Opus cit. p. 26), Thomson (Animal Chemistry, p. 610. 1843), Valentin (Opus cit. p. 540), and Thackrah (The Effects of Arts, Trades, and Professions, &c. on Health and Longevity, 2nd edit. pp. 27, 30, 64, 76, 98, 181, and 182). These experiments, however, are neither sufficiently numerous — several of them having been performed on a single individual only,— nor are they accompanied with the details necessary to enable us to contrast them with those of Mr. Hutchinson; but the results obtained in the greater number of these do not differ much from those of Mr. Hutchinson upon men of middle stature. Valentin experimented on six males, and his estimates rest on the questionable supposition that the expired air is fully saturated with moisture. Thomson experimented on 11 males and 1 female, from 14 to 33 years of age; and Mr. Thackrah's experiments were considerably more extensive, and were made on individuals of different trades and professions.

† Mr. Hutchinson has not observed any direct relation between the circumference of the chest and the respiratory power or what he terms the vital capacity. According to the experiments of Herbst (Opus cit. p. 104), and Mr. Hutchinson, the mode of determining the quantity of air which the lungs are capable of containing during life in any particular case, by measuring after death the quantity of air which can be thrown into them by inflation, is fallacious. This is probably chiefly due to the congestion of the depending parts of the lungs by blood, so frequently found after death. Both Herbst and Mr. Hutchinson have performed experiments to show the extent to which the quantity of air in forced respiration is diminished in *phthisis*.

* Among the proofs of these conclusions, advanced by Bourgery, it is stated by him that the measure of respiration of a boy of 15 years of age is 2 litres (122·054 Eng. cubic inches), and a man of 80 years 1·35 litre (82·386 Eng. cubic inches): that while a boy of 10 years and a man of 80 inspire by a forced inspiration the same quantity of air, viz. 1·35 litre, yet the *ordinary* respiration of the former is only 1 decilitre (6·102 Eng. cub. in.), while that of the latter is 9 decilitres (54·918 Eng. cub. in.); so that with a mass three times smaller, the child possesses an energy of hematose eight times greater.

than the inspired air by 6°·75 F. In the last experiment, though the inspired air was 7°·875 F. warmer than the internal temperature of the body, the expired air was only about 1°·125 F. warmer than what it is when air of the ordinary temperature is breathed. The average temperature of the expired air is, according to Valentin, 99°·5 F. when breathing in an atmosphere of moderate temperature.* According to his calculations, when a person breathes 100 cubic centimeters of atmospheric air at the temperature of 60° F., their bulk is increased to 107·87975 cubic centimeters when raised to the temperature of 99·5 F. in the lungs, since the expansive co-efficient of atmospheric air is 0·3665. As the expired air, however, contains 4·4 per cent. of carbonic acid gas, and as the expansive co-efficient of this last gas is 0·369087 the expansion of the expired air will differ slightly from what it would be were it composed of oxygen and nitrogen only, and will be 107·882197 cubic centimeters.†

It is difficult to obtain an accurate estimate of the quantity of watery vapour that escapes from the body along with the expired air. Were the inspired and expired air always fully saturated with moisture, and were their quantities, barometric pressure, and relative temperature accurately ascertained, the absolute and relative quantities of watery vapour which they contain could be calculated by certain algebraic formulæ. The atmospheric air which we breathe is sometimes saturated with moisture, more frequently the dew-point, or that at which the precipitation of the atmospheric moisture can occur, is considerably below the temperature of the air, and the number of thermometric degrees between the actual temperature of the air and the dew-point shows the degree of dryness in the air, or in other words how much it is below the point of saturation with moisture.‡ The loss of watery vapour by the lungs will evidently be regulated by the temperature of the inspired air, the quantity of watery vapour it holds in solution, the volume of air inspired, and the length of time it remains in the lungs. The lower the temperature of the inspired air, the less it approaches to the point of saturation with moisture, and the greater its volume, the greater will be the loss of watery vapour by the lungs. When the respirations are more rapid, and the sojourn of the air within the lungs is short, the same volume of expired air will probably contain less water in solution, than when its sojourn there is more prolonged, but the more frequent renewal of the air within the lungs will be more than sufficient to compensate for this.

The most correct and trust-worthy experiments to ascertain by the direct method the quantity of watery vapour in the expired air are those of Valentin and Brunner.* These experiments were performed upon seven males between the ages of 17½ and 33 years, and the maximum of watery vapour exhaled was 13156·323 Troy grains in the 24 hours; the minimum 4511·374 grains, and the average 7819·222 grains. The quantity of watery vapour in the expired air within a given time varied in the same individual; and in one experiment it was increased after drinking. In these experiments the entire quantity of water in the expired air was ascertained, so that the actual quantity given off by the fluids of the body must have been less than this; and Valentin calculates that if a person breathes atmospheric air saturated with moisture, at the temperature of 60° Fahr., and if the expired air be at the temperature of 99°·5 Fahr., and also saturated with moisture, about ⅔ of the watery vapour contained in the expired air will be furnished by the fluids of the body.† We have seen that

* Moleschott (Holländische Beiträge zu den anatomischen und physiologischen Wissenschaften, band i. heft i. S. 86. Utrecht und Dusseldorf, 1846) has more lately made experiments on the temperature of the air in the back part of the mouth, and ascertained that in a range of temperature in the external air to the extent of 12°·6 F. that there was scarcely any difference in the temperature of the expired air. In 26 experiments, — three of which were upon women, — upon individuals chiefly from 19 to 43 years of age, he found the average temperature of the expired air to be nearly 98°·6 F. The longer or shorter time which the inspired air remains in the lungs will modify the results in such experiments.

† Opus cit.

‡ According to the calculations made by the late Professor Daniell (Elements of Meteorology, vol. ii. p. 316. London, 1845) from meteorological tables, kept for 17 years consecutively, the mean temperature of London is 49°·54 F., while the mean dew-point is 44°·31, giving 5°·59 upon the thermometric scale, and 827 upon the hygrometric scale, as the degree of dryness. The mean elastic force of this watery vapour is, he says, ·342 of an inch of mercury, and a cubic foot contains 3·806 grains of moisture. The greatest degree of dryness was 49° F., or the least degree of moisture when the hygrometric scale was 235. According to Dalton's observations (Manchester Memoirs, 2nd series, vol. ii.) the medium of aqueous vapour in this climate (that of Manchester) may be estimated at ·30 of an inch of mercury due to the temperature of 44° F. This vapour, he says, is increased by the temperature of 98° in the lungs from ·30 to 1·74 inch of mercury, being an increase of 1·44 inch; but it will only be equal in weight to air of 1 inch of force, as the specific gravity of vapour is less than that of air in the proportion of 7 to 10. Valentin calculates (Opus cit. p. 533) that 100 cubic centimeters of dry air under a barometric pressure of 29·922 English inches, raised to the temperature of 99·5 F., and saturated with moisture, would be expanded to 106·488 cubic centimetres.

* Opus cit. p. 536. Lavoisier has given different estimates of the quantity of watery vapour in the expired air in his papers on respiration and transpiration in the Mémoires de l'Académie des Sciences. Hales, Menzies, and Abernethy, from experiments on themselves, and employing different kinds of apparatus, all more or less imperfectly suited for the purpose, have respectively estimated it at 9792 grs. or about 20 oz., 2880 grs. or about 6 oz., 4320 grs. or about 9 oz. Dalton and Thomson, from calculations based upon the relative quantities of watery vapour required to saturate the inspired and expired air, have estimated it respectively at 1·55 or nearly 1½ lb. Troy or 8640 grs., and at 19 oz.

† Opus cit. p. 533. Vierordt (Physiologie des Athmens, &c. S. 155. 1845) calculates from the quantity

several of the calculations of the amount of the watery vapour exhaled from the lungs proceed on the supposition that the expired air is saturated with moisture, but this has not been substantiated by the only experiments made with the view of determining this point. In Moleschott's experiments, the amount of water held in solution varied. In five out of seven experiments the watery vapour in the expired air was appreciably less than what is sufficient to saturate air of the same temperature, while in one experiment it was saturated. On taking the average difference in the seven experiments performed, as much as possible under similar circumstances, between the actual quantity of moisture in the expired air, and in air of the same temperature saturated with moisture, he found that 2420 cub. cent. (147·620 Eng. cub. inches) of the expired air would require a quantity of watery vapour additional to that already existing in it equal to 10 millegrammes (·150 Eng. Troy grains) to saturate it. From these experiments he concludes "that in the greater number of instances the expired air in man is not saturated with watery vapour, but sometimes such a saturation occurs." * Magendie observed, in experiments on dogs, that the escape of an increased quantity of watery vapour from the mouth follows the injection of water into the veins, caused, as he supposes, by the transpiration from the lungs being considerably increased.†

Animal matters in quantities too minute to be subjected to analysis are also exhaled from the lungs, and escape along with the expired vapour. The condensed vapour from the lungs, when collected in a vessel, and kept for some days, putrefies, and emits an ammoniacal smell.‡ We are also often sensible of the escape of different substances, previously taken into the stomach, along with the expired air, by their smell; and the experiments of Nysten §, Magendie*, Tiedemann†, and others, prove that various organic and mineral substances, when injected into the veins, escape in part by exhalation from the lungs.

If the inspired air, during its sojourn in the lungs, becomes increased in bulk from an increase in temperature and an addition of watery vapour, it suffers a small diminution from the absorption of part of its constituent gases. The older experimenters observed a diminution in the air respired, but as they experimented with imperfect apparatus, and transmitted the expired air through water which would absorb part of the carbonic acid gas, little confidence is to be placed in their results.‡ There can be no doubt that a greater amount of oxygen disappears from the inspired air than what is sufficient for the formation of the quantity of carbonic acid gas in the expired air, and that there is a slight diminution in the bulk of the expired air from this cause; but we cannot speak so decidedly regarding any changes in the quantity of the nitrogen. Provençal and Humboldt §, in their experiments on the respiration of fishes, and Spallanzani ||, in his experiments on snails, observed an absorption of azote: while Jurine ¶ and Nysten**, in their experiments on the human species, and Berthollet ††, Despretz‡‡, Dulong §§, and Martigny ||||, in their experiments on warm-blooded animals, and Treviranus ¶¶ in his experiments on the cold-blooded animals, observed an exhalation of azote. Dr. W. F. Edwards ***, in

of air respired by himself in a state of rest, supposing the temperature of the expired air to be 98°·6 Fahr., and saturated with moisture, the temperature of the inspired air to be 57°·2 F., and containing only its average quantity of moisture, that the quantity of water in the expired air will amount in the 24 hours to 5555·880 Troy grains, of which, on an average, 4953·993 grains may be allowed for the loss of water from the inner surface of the lungs and air passages, and 601·887 grains for the quantity previously contained in the inspired air. As, however, the body is not at rest during a considerable part of the 24 hours, the loss of watery vapour must be greater than this.

* Holländische Beiträge zu den anatomischen und physiologischen Wissenschaften, band i. S. 96. 1846.

† Compendium of Physiology, translated by Milligan, p. 395. 1831.

‡ Valentin and Brunner (Opus cit. pp. 571, 572), in their experiments on the human species, detected the presence of a minute quantity of organic matter in the expired air. This was ascertained by the sulphuric acid, through which the expired air was made to pass, becoming red. Marchand (Journal für praktische Chemie, von Erdman und Marchand, band xxxiii. S. 129. 1844), in his experiments on frogs, also observed this.

§ Recherches de Physiologie, &c. p. 145.

* Opus cit.

† Zeitschrift für Physiologie, band v. 1835. This paper is translated in the British and Foreign Quarterly Review, vol. i. p. 241. Tiedemann, in this paper, has given an account of all the experiments previously performed on this point by others.

‡ Goodwyn (Opus cit. p. 51), Pfaff (Nicholson's Journal of Natural Philosophy, vol. xii. p. 249. 1805), Dr. Alex. Henderson (Nicholson's Journal, vol. viii. p. 40), and Sir H. Davy (opus cit.), in their experiments on the human species, observed a diminution in variable proportions in the respired air; and Henderson, Pfaff, and Davy, supposed that part of this diminution was caused by the absorption of nitrogen at the lungs.

§ Mém. de la Société d'Arcueil, tom. ii. p. 388. 1809.

|| Mémoire sur la Respiration, traduit par Senebier, pp. 162, 184, and 230. 1803. An absorption of azote was not uniformly observed by Spallanzani.

¶ Mémoire couronné en 1787, par la Société Royale de Médecine, as quoted by Nysten.

** Opus cit. p. 186.

†† Mém. de la Société d'Arcueil, tom. ii. p. 459.

‡‡ Annales de Chimie et de Physique, tom. xxvi. p. 337. 1824.

§§ Magendie's Journal de Physiologie, tom. iii. p. 45. 1823.

|||| Magendie's Journal, tom. x. p. 337. 1824.

¶¶ Zeitschrift für Physiologie, band iv. Treviranus says, "in some of my experiments there was more azote than carbonic acid exhaled, and this not only in the avertebrata, but also in the frog." p. 33.

*** De l'Influence des Agens Physiques sur la Vie, p. 420. Tableaux 63, 64, and 65. 1824. Dr. Edwards concludes from his experiments that there is both a constant exhalation and absorption of azote at the lungs, and that these two actions are sometimes equal, while at other times the one preponderates over the other.

his experiments upon warm-blooded animals and reptiles, found that in some cases the quantity of azote in the air respired was increased, in others diminished, while in others it remained unchanged; but these changes in the quantity of azote did not equal the difference between the amount of oxygen absorbed and of carbonic acid exhaled. Lavoisier and Seguin *, Allen and Pepys †, Valentin and Brunner ‡, and Dr. Thomson §, in their experiments on the respiration in the human species, detected no change upon the quantity of azote.|| Boussingault ¶, by a series of comparative analyses of the aliments consumed, and of the excrements in a turtle-dove, arrived at the conclusion by this indirect method of research that azote was exhaled.

Marchand **, in his carefully-conducted experiments on frogs, detected a quantity of ammonia in the tube of his apparatus, containing the concentrated sulphuric acid, and concludes that nitrogen in this combination is exhaled from the lungs and skin.

From a review of all the experiments upon the nitrogen of the respired air, we perceive that though the evidence preponderates in favour of the exhalation of a small quantity of nitrogen from the lungs ††, yet that it is not sufficiently conclusive to justify us in stating that its operation is constant. It appears, however, from the evidence adduced, that the nitrogen in the expired air is at least frequently increased in quantity in ordinary respiration, but not to the extent of affecting materially the percentage of this gas in the respired air.* Valentin and Brunner, in their carefully conducted experiments, could detect no traces of hydrogen, carbonic oxide, or carburetted hydrogen, in the expired air.

By far the most important chemical change the atmospheric air undergoes during its sojourn in the lungs, is a diminution in the quantity of its oxygen and an increase of its carbonic acid gas; and it may be safely affirmed that all the other changes in the respired air are of trivial importance in the function of respiration, when compared with this. There can be no doubt that the conclusion drawn by Allen and Pepys from their experiments, that the amount of oxygen which disappears from the inspired air is exactly equal to the quantity required to form the carbonic acid that appears in the expired air, is incorrect; for all the latest and most accurate experiments have confirmed the general accuracy of the results obtained by Lavoisier and Davy on this point, and have satisfactorily determined that a larger quantity of oxygen disappears from the inspired air than what is sufficient to form the carbonic acid gas present in the expired air.

Percentage and absolute quantity of carbonic acid gas in the expired air. — The results of the earlier experimenters on this point are of so little value that we need not refer to them. The following results have been obtained by some of the later experimenters: —

QUANTITY OF CARBONIC ACID GAS IN THE 100 PARTS OF THE EXPIRED AIR ESTIMATED BY VOLUME.

	Average.	Max.	Min.	Difference between Maximum and Minimum.
Prout	3·45	4·10	3·30	·80 †
Coathupe	4·02	7·98	1·91	6·07 ‡
Brunner & Valentin	4·380	5·495	3·299	2·196 §
Vierordt	4·334	6·220	3·358	2·86 ||
Thomson	4·16	7·16	1·71	5·45 ¶

* Mém. de l'Académie Royale for 1789, p. 574.

† Opus cit.

‡ Opus cit.

§ Animal Chemistry, p. 612. 1843. Dr. Thomson says, in experimenting upon animals placed in vessels in which the air was renewed during the experiment, no diminution of the volume of air took place, but the case was very different when the animal was obliged to breath confined air. Nysten (Opus cit. p. 230) observed an evolution of azote in the human species, both in a state of health and disease, when the same air was breathed several times. Marchand, on the other hand (Journal für praktische Chemie, band xxxiii. S. 166), from his experiments on frogs placed in close vessels, concludes that it is exceedingly probable, if not certain, that, under this condition, these animals absorb part of the azote of the atmospheric air.

|| Vierordt remarks upon Valentin and Brunner's experiments, and the same observation applies to to the others on the human species, that the evolution of a minute quantity of nitrogen, not readily detected during the short time each of these experiments was carried on, might amount to a notable quantity in the 24 hours.

¶ Annales de Chimie et de Physique, tom. xi. p. 433. 1844. In taking the mean of the result of his experiments, he found a turtle-dove, weighing 2885·971 English Troy grains, evolved in 24 hours from the lungs 288·597 grains of carbonic acid gas, and 2·469 grs. of azote, or in volume 576·155 English cubic inches of carbonic acid and 7·689 cubic inches of azote,— a considerably smaller quantity than was obtained by Dulong and Despretz in their experiments by the direct method. This quantity of azote, according to Boussingault, constitutes the one-third of the whole of this substance which entered into the composition of the aliment of the pigeon.

** Opus cit.

†† It must, however, be remembered that in the great majority and in the most trust-worthy of these experiments in favour of the increase of the nitrogen, the exhalations from the skin were mixed with those from the lungs.

* Even supposing the nitrogen of the respired air to remain unaltered in quantity, yet as the quantity of oxygen absorbed is somewhat greater than what is necessary to form the carbonic acid exhaled along with the expired air, the percentage of the nitrogen in the inspired air will be slightly greater than in the expired air when estimated by volume.

† Thomson's Annals of Philosophy, vol. ii. p. 333. 1813. In some subsequent experiments by Prout (same work, vol. iv. p. 331) the range in the quantity of carbonic acid gas in the expired air was between 2·80 and 4·70, the minimum number occurring once only, and while he was sleepy. Prout's experiments were performed upon himself, and at every hour of the day and night.

‡ London, Edinburgh, and Dublin Philosophical Magazine, vol. xiv. p. 401. 1839. These experi-

The results obtained by Brunner and Valentin, and by Vierordt, appear especially trustworthy; and though the number of experiments is too small to enable us to deduce averages with any confidence, yet we may in the meantime consider that, in an adult male of middle age, the average quantity of carbonic acid in the expired air is about 4·35 per cent.* The quantity of carbonic acid gas in the expired air is not uniform in the same individual, but varies repeatedly, even in the course of the twenty-four hours, and these variations are determined by certain conditions of the body and of the surrounding media.

Period of the day. — Dr. Prout believed that he had discovered that the quantity of carbonic acid formed during respiration is always greater at one and the same period of the day than at any other; that this maximum occurs between 10 A. M. and 2 P. M., or generally between 11 A. M. and 1 P. M.; and that the minimum commences about $8^h\ 30'$ P. M., and continues nearly uniform till about $3^h\ 30'$ A. M. The beginning and end of the period of minimum evolution of carbonic acid he believed to be connected with the beginning and end of twilight, and he adduces some experiments in favour of this opinion. In these experiments Prout attended only to the percentage of the carbonic acid in the expired air, and took no means to ascertain the volume of air passing through the lungs at the time, — an omission which seriously diminishes their value.† Prout's results do not accord with the previous experiments of Brande ‡, nor with the subsequent experiments of Coathupe * and Vierordt. † It would appear, therefore, that the variations in the quantity of carbonic acid in the course of the day do not occur at uniform periods, independent of other circumstances, as Prout supposed. It is, however, proved by the experiments of Scharling ‡ upon the human species, by Boussingault § upon the turtle dove, and by Marchand ‖ upon frogs, that the absolute amount of carbonic acid exhaled is very considerably less during the night than during the day. Scharling gives in the following table the relative proportion of the carbon exhaled during the day and night in six individuals upon whom he experimented: —

	Night.	Day.
1. Scharling - -	1	1·237
2. Thomson - -	1	1·235
3. A Soldier - -	1	1·420
4. An adult Female -	1	1·240
5. A Boy - - -	1	1·266
6. A Girl - - -	1	1·225

The average proportion is 1 during the night to 1·237 during the day, or, in other words, nearly a fourth part more carbonic acid gas is evolved during the day than during the night.¶ How much of the diminished evolution of carbonic acid during the night is dependent upon the languor and drowsiness incident to that period, and how much upon the absence of the sun's rays and other causes, it is at present impossible to determine. It appears that this diminished evolution of carbonic acid during the night does not require the occurrence of sleep, though no doubt it is increased by sleep.

Digestion. — Seguin and Lavoisier **, in their experiments upon Seguin found that when he was in a state of repose and fasting he vitiated only 1210 cubic inches of oxygen gas in an hour, while, during digestion, this was raised to between 1800 and 1900 cubic

ments were 124 in number, and performed upon himself at almost every hour of the day between 8 A. M. and midnight. The difference between the maximum and minimum percentage is great in Coathupe's experiments; but this was only found in single cases.

§ Opus cit. p. 546. These experiments were 34 in number, and performed upon three adult males between 33 and 53 years of age.

‖ Article Respiration in Wagner's Handwörterbuch, p. 853. Vierordt's experiments were performed upon himself, were nearly 600 in number, were continued over a period of nearly 15 months, and were chiefly made between 9 A. M. and 7 P. M. Vierordt, in his Physiologie des Athmens, has given in a tabular form the results obtained in 578 experiments, p. 21—65.

¶ Animal Chemistry, p. 614. 1843. These experiments were made on 10 males and 2 females, and between 11 and 12 o'clock A. M.

* Dalton (Opus cit. p. 25), Dumas (Essai de Statique Chimique des Etres Organisés, 3me edit., p. 87. 1844), and Gay Lussac (Annales de Chimie et de Physique, tom. xi. p. 14. 1844), estimate the average carbonic acid in the expired air at 4 per cent. Apjohn (Dublin Hospital Reports, vol. v. 1830), and Macgregor (Transactions of British Scientific Association for 1840, p. 87), estimate it at 3·6 and 3·5 per cent. The estimate of Allen and Pepys (Opus cit.), and Dr. Fyfe (Dissert. Chemico-Physiol. Inaug. de Copia Acidi Carbonici e Pulmonibus inter respirandum evoluti. Edinburgh, 1814), making the average quantity 8· to 8·5 per cent., is undoubtedly considerably too high; and they were led into this error by the impediment to the free respiration occasioned by the imperfect apparatus employed.

† Thomson's Annals of Philosophy, vols. ii. and iv.

‡ Nicholson's Journal, vol. xi. p. 82.

* Opus cit.

† Physiologie des Athmens, &c., S. 66.

‡ Annalen der Chemie und Pharmacie, band xlv. s. 214. 1843. Translated in Annales de Chimie et de Physique, tom. viii. p. 478. 1843.

§ Annales de Chim. et de Phys., tom. xi. p. 445. 1844. Boussingault calculates from his experiments that, supposing the entire day to be divided into 12 hours of sleep, and 12 hours of waking, the quantity of carbon consumed in respiration by the turtle-dove during the day and night would be as follows: —

Carbon consumed in the day (English Troy grains per hour)	3·981
Carbon consumed in the night (ditto) ..	2·500

‖ Journal für praktische Chemie, von Erdman und Marchand, band xxxiii. S. 148. 1844.

¶ Annalen der Chemie und Pharmacie, band xlv. S. 236.

** Mémoire de l'Académie Royale for 1789, p. 574, 575. Jurine (Encyclopédie Méthodique, Médecine, article Air, tom. i. p. 497. 1787) has also maintained that a greater quantity of air is vitiated during digestion.

inches. Spallanzani * observed that snails, after a redundant repast, exhaled considerably more carbonic acid gas than when fasting. Similar observations have been made upon insects by Sorg † and Newport ‡, upon the Mammalia by Zimmermann §, and upon the human species by Scharling ||, Valentin ¶, and Vierordt. The most complete experiments on this point are those of Vierordt, performed on himself, the results of which are contained in the following tables. His dinner lasted from 30 minutes past 12 to 1 o'clock : —

Hours.	Pulse per minute.	Respirations per minute.	Volume of an Expiration. (In English cubic inches.)	Expired in one minute. Air. (In English cubic inches.)	Expired in one minute. Carbonic acid gas. (In English cubic inches.)	Per centage of carbonic acid in the expired air.
12	66·5	11·55	31·43	362·64	15·77	4·32
2	82·3	12·77	32·26	412·17	18·22	4·37
Difference	15·8	1·22	·83	49·53	2.45	·05

To ascertain that this increase in the quantity of carbonic acid evolved from the lungs was really dependent upon digestion, and not upon any other cause, the experiment was repeated at the same period of the day when he had not dined, and had eaten nothing since his breakfast at 7 o'clock, and the following results were obtained : —

Hours.	Pulse per minute.	Respirations per minute.	Volume of an Expiration. (In English cubic inches.)	Expired in one minute. Air. (In English cubic inches.)	Expired in one minute. Carbonic acid gas. (In English cubic inches.)	Per centage of carbonic acid in the expired air.
12	63	10	33·25	332·58	16·49	4·69
1	64	9	32·16	289·44	14·75	5·09
2	62·5	9½	35·08	334·35	15·75	4·73 **

* Mémoires sur la Respiration, p. 217—223.

† Disquisitio Physiologica circa Respirationem Insectorum et Vermium. 1805.

‡ London Phil. Trans. for 1836 and 1837.

§ The result of Zimmermann's experiments is given on Vierordt's authority in Wagner's Handwörterbuch, band ii. S. 884.

|| Opus cit. In Scharling's experiments the total quantity of carbonic acid exhaled from the body during a given time was determined, and they are, therefore, not liable to the errors of those experiments where the percentage only was ascertained.

¶ Opus cit. p. 566. Valentin states that an hour after he had taken a meal of bread and butter, the quantity of carbonic acid given off by the lungs was raised from 616·085 to 627·505 English Troy grains per hour, while after a fast of 16 hours it fell to 579·972 grains per hour.

** Physiologie des Athmens, &c. S. 91 und 94.

Notwithstanding, therefore, that Prout failed to observe any decided increase in the quantity of carbonic acid gas thrown off by the lungs during digestion, and that Mr. Coathupe maintains from his experiments that the carbonic acid in the expired air increases with increased abstinence from food, and that its *maximum* quantity is *before breakfast* and *immediately before dinner* *, we must consider the evidence detailed above perfectly conclusive in proving that the quantity of carbonic acid evolved in respiration is considerably increased after a full meal.

Fasting. — In describing the effects of digestion upon the quantity of carbonic acid evolved from the lungs, we were led to refer to the manner in which the opposite condition of the body, or that of fasting, operates. That fasting diminishes the quantity of carbonic acid in the expired air is not only proved by the facts already mentioned, but also by the experiments of Scharling upon the human species, of Boussingault upon the turtle dove, and of Marchand upon frogs. The two last experimenters found that in very prolonged fasting the quantity of carbonic acid was greatly diminished.

Alcohol. — Dr. Prout states that alcohol, and all liquors containing it which he had tried, have the remarkable property of diminishing the quantity of carbonic acid gas in the expired air much more than any thing else he had made the subject of experiment, and its effects were most remarkable when taken on an empty stomach. Vierordt mentions, in confirmation of Prout's observations on this point, that in four experiments, after having taken from one half to a bottle of wine, the percentage of carbonic acid had fallen, a quarter of an hour after this, from 4·54 to 4·01, and it continued to exercise this effect from one to two hours.†

The quantities of atmospheric air and carbonic acid are calculated in the original tables in cubic centimetres. In reducing these to English cubic inches, one cubic centimetre has been considered to be equal to ·06102523 of an English cubic inch.

* London, Edinburgh, and Dublin Philos. Magaz. vol. xiv. p. 409 and 413. The number of meals and the times at which they were taken explain the results obtained by Mr. Coathupe. He lunched at 1 o'clock P. M., and at 2 P. M. the average percentage of carbonic acid gas was raised from 3·92 to 4·17, and thus so far in accordance with the experiments mentioned above. At 5½ P.M. he took a good dinner, with a pint of wine. Now, as alcohol diminishes the quantity of carbonic acid evolved from the lungs, this might have counteracted the effects of digestion for a time. It must also be remembered that Mr. Coathupe ascertained only the percentage, not the absolute quantity of carbonic acid evolved; and Vierordt ascertained by experiment (Physiologie des Athmens, &c. S. 93) that when he drank wine at dinner the percentage of the carbonic acid in the expired air was diminished; and that, though its absolute quantity was increased, this was not nearly to the same extent as when no wine was taken. Were experimenters always to detail minutely the circumstances under which they performed their experiments, it would frequently be found, as in the present case, that results, apparently most discordant, are not so in reality.

† Wagner's Handwörterbuch, band ii. S. 884; and Physiol. des Athmens, &c. S. 97.

A strong infusion of tea has, according to Prout, an effect similar to alcohol.

According to Dr. Fyfe, when a person has taken mercury or nitric acid for some time, the quantity of carbonic acid is diminished.

Conditions of the mind. — Prout found that anxiety and the depressing passions diminish the percentage of carbonic acid in the expired air ; and Vierordt, on two occasions, observed this effect, for a short time at least, from mental emotions, both of a joyful and of an opposite nature. Scharling remarked that in those persons who felt very anxious on being enclosed in the box used by him in his experiments, the evolution of carbonic acid gas from the body was much diminished.

Exercise. — Prout states that moderate exercise, as walking, seems always at first to increase the evolution of carbonic acid, but when continued it ceases to produce this effect, and when carried the length of fatigue the quantity is diminished : that violent exercise appears to lessen the quantity from the first, or if any increase occurs, this is trifling and transitory ; and that, after violent exercise, the quantity is much lessened. In Prout's mode of experimenting, the percentage of carbonic acid having been alone ascertained, we have no certain means of judging of the changes in the *absolute* quantity of carbonic acid evolved, as the increase in the number of respirations and in the bulk of the air respired, occasioned by exercise, was not taken into account. In the experiments of Seguin and Lavoisier already referred to, it was found that Seguin, when fasting and at rest, vitiated in the hour 1210 cubic inches of oxygen gas : by an amount of exercise equal to raising 15 lbs. to a height of 613 feet, this was increased to 3200 while still fasting, and to 4600 cubic inches, while digesting food. In Scharling's experiments, where the absolute quantity of carbonic acid gas evolved from the whole body in a given time was ascertained, the quantity of carbonic acid was increased during exercise. Vierordt ascertained that during the increased respiratory movements occasioned by moderate exercise, that on an average there was an increase per minute of 18·978 English cubic inches in the expired air, containing an increase of 1·197 cubic inch of carbonic acid gas, giving, however, an increase of carbonic acid gas in the expired air of only 0·140 per cent. There can, therefore, be no doubt that the evolution of carbonic acid gas from the lungs can be considerably increased by exercise.*

Temperature. — The effects of low temperatures upon the respiratory process, as ascertained by Spallanzani and Treviranus upon snails and insects, by Marchand upon frogs, and by different observers upon the hybernating warm-blooded animals, are not applicable to the human species, since the reduction of the temperature to a certain extent induces in these animals a lethargic condition, well known under the term hybernation, altogether different from its effects upon man and the other warm-blooded animals. Seguin and Lavoisier state that in their experiments, Seguin, in a temperature of 82° Fahr., fasting and at rest, consumed, in the space of an hour, 1210 French cubic inches of oxygen ; while in a temperature of 57° Fahr., he consumed in the same time 1344 cubic inches.* Crawford †, in experiments upon guinea-pigs, ascertained that these animals, in a given time, deteriorate a greater quantity of air in a cold than in a warm medium. The most perfect experiments on this point, at least on the human species, are those of Vierordt.‡ He ascertained, by numerous trials upon himself, the effects of temperature from 37°·4 to 75°·2 Fahr. From a table, showing the results obtained, both upon the respiration and the pulse, at each degree of the centigrade thermometer within the limits mentioned, he has constructed the following shorter table, where the first table is arranged in two divisions,—the one containing the average of all the lower, and the other the average of all the higher temperatures. In the following table the measures of the expired air and carbonic acid have been reduced to English cubic inches.

	Average of the lower temperature, 47°·24 F.	Average of the higher temperature, 66°·92 F.	Difference between the higher and lower temp.
Pulse per minute	72·93	71·29	1·64
Respirations per minute	12·16	11·57	0·59
Volume of an expiration in cubic inches	33·44	31·76	1·68
Expired air per minute	406·99	366·97	40·02
——— carbonic acid per minute	18·25	15·72	2·53
Carbonic acid gas in the 100 parts of the expired air - - - -	4·48	4·28	0·20
Barometer, in English inches - - - -	29·719	29·647	

The experiments of Letellier § on warm-blooded animals agree in their results with

* G. R. Treviranus (Zeitschrift für Physiologie, vierter band, S. 29. 1831) and Newport (opera cit.) in their experiments upon insects, observed a marked increase in the exhalation of carbonic acid gas in these animals during active voluntary movements.

* Mémoires de l'Académie Royale for 1789.

† Experiments and Observations on Animal Heat, p. 311—315. 2nd edit. 1788.

‡ Wagner's Handwörterbuch, band ii. S. 878, 879, und 880. Physiologie des Athmens, S. 73—82.

§ Comptes Rendus, tom. xx. p. 795. 1845. Annales de Chimie et de Phys. tom. xiii. p. 478. 1845. Letellier has thrown the results of his experiments into the following table. He does not state whether he measured the temperature by Reaumur, or the

those of Vierordt. He found that the quantity of carbonic acid gas evolved from the body at the freezing point, was double of that at an elevated temperature, in the two mice and guinea-pig, and a little more in the canary and pigeon. There can, therefore, be no doubt that more carbonic acid gas is evolved from the body in a cold, than in a warm temperature.

Effect of the seasons.—Dr. W. F. Edwards* ascertained, by several well-devised experiments, that birds placed under exactly the same circumstances, and with the surrounding air of the same temperature, consumed more oxygen in winter than in summer, and this appears to be connected with that change in the constitution of the warm-blooded animals in the colder regions of the earth, by which they are enabled to generate more caloric in winter than in summer.

Barometric pressure.—Legallois found that when warm-blooded animals breathed air in a vessel under an atmospheric pressure reduced to 30 centimetres (11·811 English inches), the quantity of oxygen gas consumed was diminished.† Prout, on the other hand, informs us, that, in every instance in his experiments, any remarkable increase in the percentage of carbonic acid in the expired air was accompanied by a sinking barometer.‡ Vierordt tested the effects of a range of the barometric scale between 330‴ (29·309 English inches) and 340‴ (30·197 English inches), and has thrown the results into a tabular form. The measure of the expired air was calculated under the ordinary pressure of 336‴ (29·841 English inches). He found that a rise of 5‴·67, (the mean between the experiments at the lower and those at the higher pressures,) produced the following effects: —

It increased the pulsations in one minute		1·3
„	respirations	0·74
„	expired air (cubic in.)	35·746

As, however, the percentage of the carbonic acid in the expired air was greater at the lower than at the higher pressures, in the proportion of 4·450 to 4·141, the difference between the absolute quantity of that gas in the expired air at the higher exceeds so little that at the lower pressures, that it may be reckoned as nil.*

Age, sex, and constitution of body. — The quantity of carbonic acid evolved from the body is not only influenced by the ingesta and the varying conditions of the surrounding media, but also by the age, sex, and constitution of the body. The only important researches into the effects which these last conditions of the body have upon the evolution of the carbonic acid, are those of Andral and Gavarret†, and Scharling‡; and though they are far from having exhausted the subject, they possess the merit of having been carefully and accurately conducted, and of being carried on in the right direction. Andral and Gavarret availed themselves in their experiments of the apparatus suggested by Dumas and Boussingault. Part of this apparatus consists of a mask, which can be fitted air-tight to the face, and having a tube on each side, on a level with the commissures of the lips, provided with valves permitting the external air to pass in, but preventing its passage outwards. In front of the mouth there is a large aperture for conducting outwards the expired air; and to this a tube can be attached for conducting it into the receivers and other parts of the apparatus prepared for ascertaining the quantity of carbonic acid gas. A person can breathe through this apparatus without constraint; and the experiments were all performed between one and two o'clock P.M., each lasting from eight to thirteen minutes, and the individuals experimented upon were placed, as far as possible, under the same conditions with regard to food, muscular exertion, and state of the mind. They experimented upon sixty-two individuals of different ages, and of both sexes. They restricted their valuation of the quantity of carbonic

Centigrade scale, but we believe that it was the latter.

	Surrounding Temperature.		
	From 15° to 20°	From 30° to 40°	At the freezing point.
	grammes	grammes	grammes
For a Canary	0·250	0·129	0·325
For a Pigeon	0·684	0·366	0·974
For two Mice	0·498	0·268	0·531
For a Guinea Pig	2·080	1·453	3·006

* De l'Influence des Agens Physiques sur la Vie, chapitre vi.

† Annales de Chimie et de Physique, tom. iv. p. 113. 1817.

‡ Thomson's Annals of Philosophy, vol. iv. p. 335.

* Dr. Hutchinson (Medico-Chirurgical Transactions of London, vol. xxix. p. 228) has given some experiments upon the effects of an increased barometric pressure upon the frequency of the respiratory movements. These were made upon six persons before and after descending a mine, 1488 feet deep, where the barometric pressure was 1·54 inch more than at the level of the sea. As there was a difference of 10 degrees in the temperature at the top and bottom of the mine, this ought to be taken into account in judging of the results. The pulse was increased at the bottom of the mine on an average 1·3 per minute, and the respirations 2·4 per minute. The accounts given by travellers of the effects upon their respiration in elevated regions are so discordant that we can deduce no very satisfactory conclusions from them.

† Annales de Chim. et de Phys. tom. viii. p. 129. 1843.

‡ Annalen der Chemie und Pharmacie, band xlv. S. 214. 1843, translated in Annales de Chim. et de Phys. tom. viii. p. 478. 1843. In Scharling's experiments, as in those of Andral and Gavarret, the absolute quantity and not the percentage of carbonic acid gas in the expired air was determined. In Scharling's first experiments, the carbonic acid gas given off at the external surface of the body was mixed with that given off by the lungs.

acid evolved from the lungs to one hour, being perfectly aware of the fallacy of attempting to estimate from experiments so limited as to time, the quantity given off in the twenty-four hours. Scharling conducted his experiments in a different manner. He enclosed the individuals experimented on in a box, perfectly air-tight, and so large as to permit a person to work, read, or even sleep, during the experiment. Tubes were fixed in the box, to admit the external air freely, and to conduct the expired air into an apparatus fitted for determining the amount of the carbonic acid. The individuals experimented on remained in the box generally for an hour at a time, sometimes an hour and a half, but also often from thirty to forty minutes only; and precautions were taken to keep up a free circulation of atmospheric air through the box during the whole of the experiment. His experiments were performed upon six persons, of different ages and of both sexes.

Andral and Gavarret have drawn the following conclusions from their experiments:

1. The quantity of carbonic acid gas exhaled from the lungs, in a given time, varies according to the age, the sex, and the constitution of individuals; and that, independently of the weight of the body. 2. At all periods of life extending from 8 years (the earliest age subjected to experiments) up to the most advanced old age, the quantity of carbonic acid evolved from the lungs differs in the two sexes, but, *cæteris paribus*, the male exhales a considerably larger quantity than the female. This difference is most marked between 16 and 40 years of age, during which period the male generally evolves nearly twice as much as the female. 3. In the male, the quantity of carbonic acid exhaled goes on continually increasing from 8 to 30 years of age, and becomes suddenly very great at the age of puberty. After 30 years of age it begins to decrease, and this so much the more decidedly as the person approaches extreme old age, at which period it may be reduced to the quantity evolved at 10 years of age. 4. In the female also, the evolution of carbonic acid increases from infancy up to puberty; but at this period, contrary to what takes place in the male, it remains stationary, so long as the menstrual secretion continues natural. At the time the menses cease, the evolution of carbonic acid gas from the lungs undergoes a marked augmentation; but after a while it begins to decrease, as in the male, and proportionally as she advances towards old age. 5. In the female, during gestation, the exhalation of carbonic acid from the lungs equals the quantity exhaled at the period of the cessation of the menses. 6. In both sexes, and at all ages, the quantity of carbonic acid is so much the greater, as the constitution is stronger and the muscular force more developed.

The most important of the data upon which the above inferences are founded are as follows:—

In the male child, in his progress upwards from his 8th to his 15th years, the quantity of carbon given off by the lungs was raised, on an average, from 5 grammes (77·165 Troy grains) to 8·7 grammes (134·267 Troy grains) per hour; while in the female at the same age it was on an average 1 gramme (15·433 Troy grains) less per hour. In the male at 16 years of age, or soon after puberty, it suddenly increased to 157·416 Troy grains, on an average, per hour; and from this period up to the age of 20 and 25 it gradually increased, on an average, to 172·849 and 191·369 Troy grains per hour. At this point it remained nearly stationary until about 40 years of age, when it began to undergo a slight diminution, but not to any great extent until 60 years of age. Adult females, who menstruated regularly, lost, on an average, 98·771 grains only of carbon, by the lungs, in an hour,—a quantity not greater than that lost by girls. Take the average loss of carbon, by the lungs, in the male at 174·392 grains between the ages of 15 and 20 years, it is, on an average, 155·873 grains between 40 and 60 years; and 141·953 grains between 60 and 80 years. In the female, at the period of the cessation of the menses, the loss of carbon is suddenly elevated from an average of 98·771 to 129·637 grains per hour; and a similar elevation, and nearly to the same extent, was observed in four females during pregnancy. In females between 50 and 60 years of age, the loss was 112·660 grains, and between 60 and 80 it was, on an average, 104·944 grains in an hour. In one female of 82 years, it was 92·595 grains, and in a male of 102, but remarkably hale for his years, it was 91·590 grains. In a male, aged 26, and remarkable for his muscular development, the loss was as high as 217·105 grains, while in another male, aged 45, of moderate height, but extremely feeble muscular development, it amounted on an average only to 132·723 grains an hour.* Scharling, after allowing seven hours for sleep to an adult, and nine for a child, calculates, from his experiments on six individuals, the amount of the loss of carbon from the body as follows:—

	Age—years	Weight of body in Troy lbs.	Quantity of carbon exhaled in grains. In 24 hours.	In 1 hour.
Male - -	16	154·73	3453·90	143·91
—— - -	28	219·70	3699·50	154·14
—— - -	35	175·49	3386·77	141·11
Average of men	$26\frac{1}{2}$	183·30	3513·39	146·39
Boy - -	$9\frac{3}{4}$	58·96	2054·53	85·60
Girl - -	10	61·64	1929·89	80·41
Aver. of children	$9\frac{7}{8}$	60·30	1992·21	83·10
Woman -	19	149·41	2540·88	105·87 †

* Brunner and Valentin (opus cit. p. 567), from

In these experiments of Scharling the evolution of carbonic acid by the skin was included, with that evolved through the mouth and nostrils; and the quantity is calculated for the twenty-four hours. But in some subsequent experiments, by uniting the use of the mask used by Andral and Gavarret with the box, he has been enabled to ascertain the relative amount of the loss by these two different channels in an hour. In other respects, he has endeavoured to assimilate his experiments, in regard to the hour of the day, &c., to those of Andral and Gavarret, and has given the following comparative view of the results: —

	Total quantity of carbon from the whole body in Troy grains.	Carbon from general surface of body.	Carbon expired through the mouth and nostrils in Troy grains.	
			Scharling.	Andral and Gavarret.
1. Male aged 28 years	181·183	5·756	175·426	191·369
2. — — 16 —	169·763	2·793	166·969	157·416
3. Boy — 9¾ —	101·086	1·913	99·172	91·054*
4. Young Woman 19 —	128·340	4·197	124·143	108·031
5. Girl - - 10 —	95·622	1·913	93·709	92·598 †

Influence of the respiratory movements upon the evolution of carbonic acid from the lungs. — This point has been particularly examined by Vierordt in 171 experiments upon himself, and he has ascertained that the frequency, extent, and duration of the respiratory movements have a marked effect, not only upon the relative proportion of the carbonic acid gas in the expired air, but also upon the absolute quantity evolved from the lungs in a given time. ‡ We shall afterwards find, when we come to describe the theory of respiration, that the results obtained by Vierordt are of considerable importance in a theoretical point of view.

Frequency of the respiratory movements. — When the number of respirations is less than usual, the percentage of the carbonic acid in the expired air is increased, while its absolute quantity is diminished; on the other hand, when the respirations are more frequent than usual, the percentage of carbonic acid in the expired air is diminished, while its absolute quantity is increased. Vierordt endeavours to point out that the diminution in the percentage of the carbonic acid gas in the expired air when the respirations are more frequent, probably bears a certain proportion to their frequency or length per minute, supposing their bulk to be the same. The operation of this law, according to Vierordt, may be illustrated as follows. Let us take the average number of respirations in a state of rest as 12, and suppose these to be doubled or increased to 24, the relative percentage of carbonic acid will be diminished by 0·8; if the number of respirations be again doubled, or increased to 48, the carbonic acid will suffer a still further diminution of 0·4 per cent.; and if the respiration be again doubled, and increased to 96 per minute, the carbonic acid will suffer a farther reduction of 0·2 per cent. On the other hand, if the number of respirations be less than 12 (here taken as the normal number of respirations by Vierordt) by one half or reduced to 6 in the minute, the relative percentage of carbonic acid will be increased above what it is in the normal frequency by 1·6. If the percentage of carbonic acid in the expired air be 4·1, when the respirations are 12 in the minute, it will be 5·7 per cent. when the respirations are 6, and 2·7 per cent. when they are 96 in the minute. Proceeding upon the existence of this law, he supposes that if the respirations were increased from 96 to twice that number, or 192, the percentage of the expired air would suffer a farther reduction of only 0·1 per cent.; in other words, it would be reduced from 2·7 to 2·6 per cent. This last ratio, viz. 2·6, he believes to be the smallest percentage of carbonic acid gas that the expired air can present. If Vierordt be correct in supposing that the percentage of carbonic acid in the expired air has a fixed arithmetical proportion to the frequency or length of the respiratory movements, we could, after determining the normal number of respirations, the bulk of air expired, and the percentage of carbonic acid

six experiments on themselves, calculate that 172·664 Troy grains of carbon were thrown off from the lungs in an hour.

† This table is given in the form into which it has been thrown by Hannover (De Quantitate relativa et absoluta Acidi Carbonici ab homine sano et ægroto exhalati, p. 17. 1845) and the kilogrammes and grammes in the original table have been reduced to Troy pounds and Troy grains.

* As the boy upon whom Scharling experimented was of slender form, he has taken the average of the results of Andral and Gavarret upon two boys of 10 and 8 years as the standard of comparison in this case.

† Wöhler and Liebig's Annalen der Chemie und Pharmacie, band lvii. S. 1. 1846. The male adult and the boy were naked during the experiment.

‡ Physiologie des Athmens, vierter abschnitt, S. 102—149.

gas, when the body is in a state of rest, be able to determine both the relative and the absolute quantity of carbonic acid gas in the expired air from the number of respirations alone, when these are either increased above, or diminished below the normal number, provided the bulk of each respiration continues equal. He has constructed the following table to illustrate the variations in the absolute quantity of carbonic acid gas occasioned by alterations in the frequency of the respiratory movements. The normal number of respirations is supposed to be 12, the average bulk of each respiration to be 500 cubic centimetres (30·5 English cubic inches), and the percentage of carbonic acid to be 4·1.

Number of respirations in a minute.	Percentage of carbonic acid in the expired air.	Volume of the expired air in a minute.	Volume of carbonic acid gas in the expired air in a minute.	Volume of carbonic acid gas in each expiration.
		Measured in English cubic inches at a temperature of 98°·6 F., and under a barometric pressure of 29·841 English inches.		
6	5·7	183·000	10·431	1·738
12	4·1	366·000	15·006	1·250
24	3·3	732·000	24·156	1·006
48	2·9	1464·000	42·456	0·884
96	2·7	2928·000	79·056	0·823

Bulk of the air expired.—The quantity of air thrown out of the lungs at each expiration has also an influence upon the percentage and absolute quantity of carbonic acid gas in the expired air. Vierordt, in six experiments, found that while the average of carbonic acid gas in the expired air in a normal expiration in a state of rest was 4·78 per cent., in the deepest expiration he could make, it was 4·05 per cent.

The stoppage of the respiratory movements for a time has also a marked effect upon the quantity of carbonic acid in the expired air. Vierordt has made four series of experiments upon himself to ascertain the extent of this influence upon the quantity of carbonic acid evolved from the lungs. In the first series he shut his mouth and held his nose from 20 to 60 seconds (the longest period he could continue the experiment), and then made the deepest possible expiration. In the second series he made the deepest inspiration possible, then suspended the respiratory movement for a longer or shorter time, at the termination of which he made the deepest expiration. This experiment he was able to prolong to 70, 90, and even 100 seconds. In the third series he made an ordinary inspiration before suspending the respiratory movements, and after this suspension had continued for different periods up to 30 seconds, he made an ordinary expiration. The fourth series of experiments was to ascertain the period of time after the stoppage of the respiratory movements when the percentage of carbonic acid gas becomes uniform in the different parts of the lungs and air passages, and this he found took place after 40 seconds. He has arranged the results of the three first series of experiments in several tables, exhibiting the difference between the percentage and absolute quantity of carbonic acid gas in the expired air at various periods, after the suspension of the respiratory movements under the circumstances mentioned, and when the respiratory movements proceed in the normal manner. In the first series of experiments, the percentage of the carbonic acid in the expired air, after the respiratory movements had been suspended 20 seconds, was higher by 1·73 than when these movements were normal, but the absolute quantity evolved from the lungs had diminished by 2·642 English cubic inches, and at the end of 55 seconds its percentage had increased 2·32, but its absolute quantity had diminished to the extent of 12·382 cubic inches. In the second series of experiments, where the deepest possible inspiration preceded, and the deepest possible expiration followed, the suspension of the respiratory movements, the absolute quantity of carbonic acid gas evolved from the lungs, for the first 15 seconds, was somewhat more than what would have occurred had these movements proceeded in the normal manner, but after this it began to diminish; and when the respiratory movements had been suspended for 95 seconds, it was diminished to the extent of 14·078 English cubic inches, though its percentage had considerably increased. At the end of the 100 seconds, the percentage of the expired air was 3·08 above the normal quantity in ordinary respiration. In the third series of experiments, the carbonic acid in the expired air, at the end of 30 seconds, was 1·55 per cent. above the normal quantity. These experiments prove, therefore, that when the respiratory movements have been suspended for a time, the percentage of carbonic acid in the expired air will increase, but the absolute quantity evolved from the lungs will be diminished, so that the increase in the percentage of this gas does not by any means compensate for the diminished quantity of air passing through the lungs.

When the same air is breathed more than once, the quantity of carbonic acid in it is increased. Allen and Pepys * state that air, passed 9 or 10 times through the lungs, contained 9·5 per cent. of carbonic acid gas; and the greatest quantity obtained, in air breathed as often as possible, was 10 per cent. Mr. Coathupe † found the average quantity of carbonic acid gas, in air in which warm-blooded animals had been confined until they were becoming comatose, to be 10·42 per

* Philos. Transact. of London for 1808.

† Opus cit.

cent.; while, if they were allowed to remain in it until they had become asphyxiated, it contained 12·75 per cent. Vierordt, in three experiments, breathed, from $1\frac{1}{2}$ to 3 minutes, a volume of air amounting to 427 English cubic inches, and found, on an average, the carbonic acid gas 1·5 per cent. above that contained in air breathed only once.

The percentage of carbonic acid in the expired air differs at different periods of the same expiration. As the air expelled in the first part of an expiration consists chiefly of that contained in the trachea and upper part of the air passages, its amount of carbonic acid gas must necessarily be smaller than that expelled at a later period of the expiration. Allen and Pepys found the carbonic acid gas in the first and last portions of air in a deep expiration to differ as widely as 3·5 and 9·5 per cent. Dalton states that while the average carbonic acid in an ordinary expiration is 4 per cent., the last portion of a forced expiration contains 6 per cent. Vierordt divided the air of an ordinary expiration as far as possible into two equal parts, and in twenty-one experiments ascertained that while the average quantity of carbonic acid in the whole expiration was 4·48, the first half contained 3·72 per cent., and the last half 5·44 per cent. We have already seen, that Vierordt concludes from his experiments that the air, after a sojourn of about 40 seconds in the respiratory apparatus, has the same percentage of carbonic acid gas in the different parts of the lungs and air passages.

From the above details, it must be obvious that nearly all the attempts made to estimate exactly the average quantity of carbon evolved in the form of carbonic acid gas from the body in the 24 hours are entitled to very little confidence. The greater number of these are founded on a few experiments performed upon one or a very small number only of individuals in a state of rest, and upon the result of a few respirations in some cases performed under constraint. The estimate of the amount of loss of carbon in the 24 hours from the lungs and external surface of the body, based upon the direct method of experiment, in which the greatest number of the circumstances that influence the evolution of carbonic acid gas from the lungs were taken into account, is undoubtedly that of Scharling, though this even must be regarded as an approximation only to the truth. Suppose we take the average estimate of the two adult males between 28 and 35 years of age for the 24 hours, as given by Scharling *, the loss of carbon by the lungs and skin is 3543·13 Troy grains, or 7·382 oz. Troy. † Liebig ‡ has endeavoured to ascertain the quantity of carbon lost at the lungs and skin in the 24 hours by the indirect method of research, which he maintains to be by far the most trust-worthy. He proceeded to ascertain the quantity of charcoal in the daily food and drink of a body of soldiers, and after deducting the comparatively small quantity of this substance that passes off in the fæces and urine, the remainder was taken as the amount of carbon that unites with oxygen, and escapes in the form of carbonic acid gas by the lungs and skin. From the data thus obtained he calculates that an adult male, taking moderate exercise, loses 13·9 oz. of carbon daily by the lungs and skin; and that 37 oz. of oxygen gas must be daily absorbed from the atmospheric air for the purpose of converting this charcoal into carbonic acid gas. From similar experiments upon the inmates of the Bridewell at Marienschloss (a prison where labour is enforced), he calculates that each individual lost in this manner 10·5 oz. of carbon daily; while in another prison, where the inmates were deprived of exercise, this loss amounted only to 8·5 oz. daily.* Allowing that this indirect method of research is more accurate than the direct, — a point which we are not at present prepared to determine, — the accuracy of the data upon which Liebig's inferences rest regarding the quantity of carbonic acid exhaled from the lungs and skin in an adult using moderate exercise, has been called in question by Scharling. † He endeavours to prove, by an analysis of the food and drink allowed to the sailors on board of his Danish Majesty's vessels of war, that the whole carbon taken daily into the body of each of these individuals must be somewhat less than $10\frac{1}{2}$ oz.; yet these sailors are subjected to harder work than ordinary seamen. ‡

The quantity of carbonic acid gas evolved from the body in respiration varies greatly in the different divisions of the animal kingdom. It is greater in birds, in proportion to their bulk, than in the cold-blooded vertebrata, and still smaller in the invertebrata, with the exception of insects. § The ascertainment not

* Vide table given in p. 350.

† The estimates of the average loss of carbon, in the form of carbonic acid gas, from the lungs in the twenty-four hours by other experimenters, differ considerably. Lavoisier and Seguin estimated the loss of carbonic acid gas at 14,930 cubic inches, which they believed would yield 2776·304 grains Troy; Messrs. Allen and Pepys at 39,534 cubic inches of carbonic acid gas, containing rather more than 11 oz. Troy of carbon; and Mr. Coathupe at 10,666 cubic feet of carbonic acid gas, yielding 2386·27 grains, or 5·45 oz. avoirdupois. Vierordt, from numerous experiments on himself, ascertained that when in a state of rest the quantity of carbonic acid gas exhaled from the lungs per minute was for the maximum 452 cubic centimètres (27·572 Eng. cub. in.), for the minimum 177 cub. cent. (10·797 Eng. cub. in.), and for the average 261 cub. cent. (12·261 Eng. cub. in.), so that the relation of the minimum and maximum was 100 : 255. If the quantity of carbonic acid evolved from the lungs differs so much at different times in the same individual in the minute, and is so materially influenced by the varying conditions of the body, how difficult must it be to ascertain the average quantity during the twenty-four hours.

‡ Animal Chemistry, &c., edited by Dr. Gregory, p. 13; 3rd edit. 1846.

* Opus cit. p. 46.

† Annalen der Chemie und Pharmacie, von Wöhler und Liebig, Band lvii. S. 1. 1846.

‡ Opus cit. p. 9.

§ The results of the various experiments upon

only of the absolute quantity of carbon which escapes from the body in the form of carbonic acid gas in the different classes of animals, but also the relative proportion of this to the weight of the body, is a matter of considerable physiological interest, especially with reference to the source of animal caloric. From the experiments of Scharling, Andral, and Gavarret, it is evident that the young of the human species relative to their weight consume considerably more oxygen gas, and evolve more carbonic acid gas by respiration, than the middle-aged; and that the latter again evolve more carbonic acid than those far advanced into old age. Valentin and Brunner have calculated, from experiments performed on Valentin, who at the time was 33 years of age, that for every gramme weight (15·433 Troy grains) of his body, there was evolved ·0089 Troy grain of carbonic acid gas, containing ·0024 Troy grain of carbon; and this calculation approximates pretty closely to one based upon the results of Andral and Gavarret upon the evolution of carbon, combined with those of Quetelet upon the average weight of the body at this period of life. * The following table, calculated from the experiments of different observers, to show the quantity of carbon consumed in the 24 hours for every 100 grammes weight (1543·3 Troy grains) of the body in the four divisions of the vertebrata, is given by Vierordt: —

	Troy Grains.	
Tench (Provençal and Humboldt)	·370 =	1
Frog (Marchand)	1·342 =	4
Man (Scharling)	4·506 =	12
Pigeon (Boussingault)	42·317 =	114

Quantity of oxygen absorbed at the lungs. — That a quantity of oxygen gas greater than what is necessary to form the carbonic acid gas in the expired air disappears from the inspired air, is now placed beyond a doubt. The quantity of oxygen gas that disappears from the inspired air by absorption at the lungs is not uniform, even in the same individual, for any length of time, and the variations in this respect are in all probability determined by the same circumstances which affect the evolution of carbonic acid gas, the absorption of oxygen being increased when the evolution of carbonic acid is increased, and *vice versa*. Dalton calculated that he himself respired 500 cubic feet of atmospheric air, containing 105 cubic feet of oxygen, in the 24 hours, and that 25 cubic feet of the oxygen, weighing 15,120 grains, or 2·6 lbs. Troy, were absorbed at the lungs. Valentin and Brunner, in 34 analyses of the air expired by 3 individuals between 33 and 54 years of age, found the *average* quantity of oxygen gas to be 16·033, the *maximum* 17·246, and the *minimum* 14·968 parts by volume in the 100 parts of the expired air. Proceeding on these results of Valentin and Brunner, we may estimate the average amount of oxygen that disappears from the inspired air at 4·78 by volume in the 100 parts.

While the experiments upon the relation of the quantity of oxygen absorbed at the lungs to that of the carbonic acid gas evolved, made by Lavoisier, Sir H. Davy, and Dalton on the human species, by Legallois, Dulong, Despretz, and Dr. W. F. Edwards upon the warm-blooded animals, by Treviranus upon several cold-blooded animals, and by Marchand upon frogs, all concur in making the oxygen absorbed greater than what is necessary to form the carbonic acid exhaled, they exhibit very considerable differences in the relative proportions of the absorbed oxygen and exhaled carbonic acid gas. In some of these experiments, the oxygen absorbed was considerably greater than what is necessary to form the carbonic acid gas. In Marchand's experiments on frogs subjected to prolonged fasting, the relation of the oxygen absorbed to the carbonic acid evolved constantly increased, until it amounted to between 410—430 : 100. * Valentin and Brunner, in their experiments on the human species, found the relative proportions of these two gases to approximate so closely to their diffusive volumes, that they believed the small difference between the results obtained by actual experiment and when calculated according to the law of the diffusion of gas, discovered by Graham, arose from incidental circumstances; and as the diffusive volume of carbonic acid gas is to oxygen gas as 1 : 1·1742, they maintain that for every 1 volume of carbonic acid gas evolved from the blood, 1·1742 volume of oxygen gas is absorbed. Valentin has given the following table, constructed from facts furnished by Quetelet, Andral, and Gavarret, conjoined with calculations of the relative quantities of oxygen absorbed and carbonic acid evolved according to the law of the diffusion of gases, to exhibit the weight of the body, the quantity of carbon consumed in respiration, and the probable amount of oxygen absorbed and carbon consumed at the different periods of life in the human species †: —

the quantity of carbonic acid evolved in respiration in different classes of animals up to the period when the work was published, are thrown into a tabular form in Burdach's Physiologie, 2nd edition, translated by Jourdan, tom. ix. p. 512.

* A table constructed on these data, exhibiting the probable quantity of carbon which combines with oxygen to form the carbonic acid gas evolved at the lungs at different ages in the human species, is given at p. 569 of Valentin's Lehrbuch.

* At page 563 of Valentin's Lehrbuch are two tables exhibiting the relative proportions of oxygen gas absorbed and carbonic acid evolved, as ascertained by direct experiment, and as calculated according to the law of the diffusion of gases. We shall have occasion to make some remarks on this subject when we come to discuss the theory of respiration.

† Opus cit. p. 571. The weights and measures in the original table are here reduced to Troy weight and English cubic inches.

Years of age.	Average weight of body in Troy pounds.	Carbon consumed, in Troy grains.		Quantity of oxygen which disappears from the inspired air. In grains.		Overplus of oxygen above what is necessary to form the carbonic acid gas. In Troy grains.		Volume of oxygen that disappears from the inspired air under a pressure of 29·92 inches, and a temperature of 32° F. In English cubic inches.	
		In 1 hour.	In 24 hours.	In 1 hour.	In 24 hours.	In 1 hour.	In 24 hours.	In 1 hour.	In 24 hours.
8	59·62	77·165	1864·306	240·955	5782·806	35·233	845·604	526·907	12645·770
15	124·34	134·267	3222·410	419·252	10062·069	61·207	1468·974	1154·142	27699·422
16	143·05	166·676	4000·233	520·447	12490·852	75·976	1823·439	1432·669	34384·076
18—20	164·13 to 174·15	175·936	4222·468	549·399	13184·782	80·359	1928·631	1512·432	36298·371
20—24	174·15 to 184 36	188·282	4518·782	587·904	14110·083	85·622	2054·934	1618·436	38842·098
40—60	184·36 to 175·49	155·873	3740·959	486·710	11681·052	71·099	1706·395	1339·847	32156·346
60—80	175·49 to 164·02	141·983	3407·606	443·34	10640·250	64·926	1558·239	1220·478	29291·495†

From the details given above we may obtain information of considerable importanen on several practical points. A consideratioe of the large quantity of atmospheric air passing through the lungs in the 24 hours, and the extent to which it is vitiated by this in the removal of a part of its oxygen and the substitution of a quantity of carbonic acid gas, will assist us in acquiring definite information regarding the amount of ventilation required in the apartments of our private and public buildings. It appears that between 400 and 500 cubic feet of atmospheric air pass daily through the lungs of an adult enjoying moderate exercise; and the estimate of Dalton, that 23 cubic feet of oxygen gas are, during the same period, aborbed at the lungs, is probably not far from the average. The same air cannot be breathed twice without inducing prejudicial effects, so that at each inspiration entirely fresh air ought to be supplied, or the air already breathed ought to be so largely diluted by the admission of fresh air as to be restored very nearly to its original composition. Leblanc informs us, that in the Chamber of Deputies in Paris, where the system of ventilation is based upon the principle of furnishing to each individual from 10 to 20 metres cubes (353·316 to 706·331 English cubic feet) of air per hour, the air issuing from the apartment contained from 2 to 4 of carbonic acid gas in the 1000 parts by weight.* The quantity of pure atmospheric air here furnished is probably somewhat insufficient, if the presence of 1 part of carbonic acid in the 100 of atmospheric air be likely to act prejudicially when breathed for a long time continuously. From Dr. Snow's experiments, it appears that the prejudicial effects of breathing air deteriorated by respiration, is not entirely due to the presence of an increased quantity of carbonic acid gas, but also in a considerable degree to the diminution of the oxygen. He found that birds and mammalia introduced into an atmosphere containing only from 16 to 10½ per cent. of oxygen soon died, though means were adopted for removing the carbonic acid formed by respiration.* The increase of the carbonic acid gas to 12 and 20 per cent., provided the oxygen gas was still as high as 21 per cent., did not appear to enfeeble the vital actions more rapidly than the diminution of the oxygen to the extent above stated. Any notable diminution in the percentage of the oxygen gas, even when no carbonic acid is present, cannot take place without danger to the warm-blooded animals†, and the carbonic acid in the air respired acts more or less energetically in destroying life, as it has been produced at the expense of the oxygen of the air, or been added to it already formed.‡

* Annales de Chimie et de Physique, troisième série, tom. v. p. 241. 1842. In the Model Prison at Pentonville from 30 to 45 cubic feet per minute, or from 1800 to 2700 cubic feet per hour, of pure fresh air is made to pass into every cell. (Report of the Surveyor-General on the Construction, &c. of Pentonville Prison. 1844.)

* Edinburgh Medical and Surgical Journal, vol. lxv. 1846. A green-linnet was confined in a vessel containing 2000 cubic inches of air, consisting of 16 of oxygen and 84 of nitrogen in the 100 parts by volume, and it died in ten minutes. A mouse was introduced into the same vessel filled with air containing 10½ per cent. of oxygen, and in five minutes it was no longer able to stand.

† There is a marked difference in this respect between the cold-blooded and warm-blooded animals. Vauquelin (Annales de Chimie, tom. xii. p. 271. 1792) in his experiments upon some snails, found that when confined in a quantity of air, all the oxygen had disappeared at the time of their death; and Spallanzani observed the same thing in a few of his experiments on the same animals. Matteucci (Leçons sur les Phénomènes Physiques des Corps Vivants, p. 115. 1847), obtained similar results on a torpedo confined in a limited quantity of water.

‡ Dr. Snow infers from his experiments on the lower animals that in the human species "five or

The experiments on the effects of diminished frequency of the respirations in reducing the amount of carbonic acid gas evolved from the blood in a given time, are in accordance with observations made on the state of the blood and its circulation, when this condition has been induced in man or in the other warm-blooded animals. A diminution in the frequency of the respiratory movements occasionally occurs to a notable extent in the course of some diseases, and this deserves the careful attention of the practitioner, as it is likely to lead to very serious consequences.*

The greater length of time that the respirations may be suspended without inducing insensibility, when a deep expiration followed by a deep inspiration has immediately preceded, affords additional illustration of the procedure which a person ought to adopt when he wishes to suspend, during diving, &c., the respirations for the longest period consistent with his safety. The manner and the order in which the vital actions are brought to a stand when the chemical changes between the blood and the atmospheric air are arrested, have been discussed under the article ASPHYXIA.†

Experiments have been made by Nysten*, by Mr. Macgregor†, Dr. Malcolm‡, and by Hannover§, upon the quantity of carbonic acid gas evolved from the lungs in some diseases, but these have not yet been carried sufficiently far to furnish us with any practical or theoretical conclusions of importance.

Differences between arterial and venous blood. — A knowledge of the chemical and physical differences between arterial and venous blood, or, in other words, between the blood immediately before and immediately after it has passed through the lungs and been subjected to the action of the atmospheric air, constitutes part of the data requisite for discussing the Theory of Respiration. Although many able chemists and physiologists have of late years directed their attention to this subject, yet, from its inherent difficulties, much discrepancy of observation and conflicting evidence still require to be cleared up and reconciled. Most, if not all, of the comparative analyses of the venous and arterial blood hitherto published are of considerably less value for our present purpose than they may at first appear, since only those of the venous blood flowing from the right side of the heart, and the arterial blood flowing from the left side of the heart or along the arteries, ought properly to be taken into account. The blood returning along the veins of the abdominal viscera, and entering the heart by the cava inferior, differs in composition from that entering the heart by the cava superior, for, independently of other reasons, a quantity of water and certain substances taken into the stomach are absorbed by the mesenteric and gastric veins. The composition of the blood in the large veins at the lower and lateral parts of the neck must also be somewhat affected by the lymph and chyle poured into that portion of the venous system. The analyses of venous and arterial blood taken at the same time from the carotid artery and the jugular vein, — the plan most generally followed in these researches, — are better fitted for throwing light upon the changes the blood undergoes in the perform-

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six per cent. by volume of carbonic acid gas cannot exist in the air without danger to life, and that less than half this amount will soon be fatal, when it is formed at the expense of the oxygen of the air." (Opus cit. p. 54.) Leblanc ascertained that an addition of 3 or 4 per cent. by weight of carbonic acid formed by the combustion of charcoal, and at the expense of the oxygen of the air respired, proved instantly fatal to dogs, while it required the addition of 30 or 40 per cent. of pure carbonic acid gas to the atmospheric air to produce the same effect. The great activity of air deteriorated by the burning of charcoal in producing asphyxia, Leblanc attributes to the presence of carbonic oxide. He states that birds placed in air containing one per cent. of this gas, die in two minutes (Opus cit. pp. 240 and 245). Legallois (Annales de Chimie et de Physique, tom. iv. p. 113. 1817) had previously performed experiments, from which it may be inferred that an addition of somewhat more than 20 per cent. of carbonic acid to the atmospheric air, is sufficient to bring the evolution of carbonic acid from the blood in the lungs to a stand in the warm-blooded animals, and that, when the percentage of carbonic acid in the inspired air is increased to above 30, part of this gas is absorbed by the blood.

* We have given some illustrations of this in pointing out the manner in which division of the vagi nerves causes death. (Edinburgh Medical and Surgical Journal, vol. li. p. 298 to 302. 1839.)

† We have published a series of experiments (Edinburgh Medical and Surgical Journal, vol. lv. 1841) which go to support the account given of the manner in which the vital actions are arrested in asphyxia in the *article* referred to. In this we obtained satisfactory proof of the opinion of Bichat upon the effects of the venous blood in suspending the sensorial functions. In an excellent experimental essay on this subject, published subsequently to our essay (Edinburgh Med. and Surg. Journal, vol. lxiii. 1845), the author maintains, in opposition to the doctrine laid down in the article ASPHYXIA, "that the flow of blood through the lungs is arrested in consequence of the venous blood acting as an excitant to the minute branches of the pulmonary veins and causing their contraction." In our experiments we found that, when the suspension of the respiration had been carried so far as to arrest the flow of blood through the lungs, the admission of atmospheric air was *instantaneously* followed by the renewal of the passage of the blood to the left side of the heart, — a fact incompatible with this opinion, seeing that the blood-vessels are endowed with that kind only of contractility which manifests itself by slow contractions and equally slow relaxations.

* Recherches de Physiologie et de Chimie Pathologique. Seconde section. 1811.

† Edinburgh Monthly Journal of Medical Science, vol. iii. p. 1. 1843.

‡ Transactions of British Scientific Association, for 1840, p. 87.

§ De Quantitate relativa et absoluta Acidi Carbonici ab Homine sano et ægroto exhalati. 1845. Hannover, in his experiments, employed the apparatus of Scharling, and was enabled to ascertain the *absolute* quantity of carbonic acid evolved from the body; while the other experimenters ascertained its percentage only. There can be no doubt that the plan adopted by Hannover is the one which ought to be followed.

ance of nutrition and secretion than of respiration.

The most marked difference, more especially in warm-blooded animals, between arterial and venous blood is that of colour, — arterial blood being of a scarlet red, and venous blood of a dark Modena hue. The extent of this difference of colour between the blood in the arteries and in the veins varies in the different vertebrata, and is greater in birds and in the mammalia than in reptiles and fishes; and it also varies in different conditions of the body and surrounding media in the same animal. In animals exposed to artificial high temperatures*, or living in warm climates†, when the energy of the respiratory function is naturally diminished, the venous blood may be of a brighter colour than usual, while the arterial may be less so, and it may then be difficult to distinguish the one kind from the other. In certain cases of high febrile excitement of the circulation, as in acute rheumatism when the blood passes rapidly and abundantly through the lungs, the blood in the veins may be of a scarlet colour: on the other hand, where the aëration of the blood is imperfect, as during the state of hybernation, in certain diseases, or from some mechanical impediment to the free passage of the air into the lungs, the blood flowing along the arteries approaches more or less the dark colour of venous blood.

The temperature of the arterial blood in the left side of the heart, aorta, and large vessels springing from it, is higher than the venous blood by from 1° to 2° Fahr., according to Dr. John Davy ‡, and 1°·01 C (1°·818 Fahr.) on an average, according to Becquerel and Breschet. § According to Dr. Davy, the capacity of venous blood for caloric is 852, that of arterial blood 839. ||

The specific gravity of venous is somewhat greater than that of arterial blood. Dr. Davy gives the specific gravity of arterial blood as 1050, that of venous as 1053. ¶ Some of those who have published analyses of both kinds of blood, procured more solid materials and less water from venous than from arterial blood; others again have obtained the opposite result; while Denis, in his analysis of the blood of a dog, observed no difference in this respect. The number of instances, — taking the more trust-worthy analyses only into account, — where the quantity of water was greater in the arterial than in the venous blood decidedly preponderates. In all probability the relative quantity of water in the two kinds of blood is determined by the relative extent of the loss of that fluid by the arterial blood at the kidneys, lungs, skin, &c., and of the supply entering the veins from without, but chiefly through the mesenteric veins.

A larger quantity of fibrin has been obtained by some analysts from arterial than from venous blood in man and in the domesticated animals; others again have procured a larger quantity from venous than from arterial blood; while a few have obtained dissimilar results in their analyses of these two kinds of blood in different genera of animals, and even in different individuals of the same species.* In the greater number of the analyses, however, more fibrin was obtained from arterial than from venous blood. † According to Denis and Scherer, the fibrin of the two kinds of blood differs in regard to its solubility in nitre. When a portion of well-washed fibrin from venous blood is triturated with a third part of nitre, and four times its weight of water, and a small quantity of caustic potass or soda is then added, it dissolves into a gelatinous mass, having the chemical characters of albumen; while the fibrin from arterial blood similarly treated undergoes no such changes.

The blood-corpuscles are more abundant in arterial than in venous blood, according to Prevost and Dumas, Lecanu and Denis; according to Meyer, Hering, and Nasse, they are more abundant in the venous blood; while the analyses of Letellier and Simon tend to show that the proportion is fluctuating. According to Simon, the blood-corpuscles of arterial contain less hæmatin than venous blood, while the quantity of globulin is variable. Mulder states that the chemical composition of hæmatin is the same whether derived from arterial or venous blood.‡

The statements made regarding the relative proportions of the albumen, fat, osmazone, and salts in the two kinds of blood, differ too much to justify us in attaching any importance to them, — a remark which, as yet, we are afraid applies with too much truth to most of the other statements regarding the chemical differences between the two kinds of

* Crawford. Experiments and Observations on Animal Heat, p. 309. 3rd edit.

† Dr. J. Davy. London Phil. Transact. for 1838, p. 28.

‡ Researches, Physiological and Anatomical, vol. i. p. 147. 1839. At page 211 of the same volume, another series of experiments is given, in which the difference in temperature varied from 1° to 3° F.

§ Annales des Sciences Naturelles, 2me série, tom. vii. p. 94. 1837. Becquerel and Breschet, in their experiments, used a thermo-electric apparatus. They found the difference of temperature between the two kinds of blood diminish as the blood-vessels are more distant from the heart.

|| Researches, Physiological and Anatomical, vol. i. p. 146.

¶ Opus cit. vol. ii. p. 22.

* Nasse (article Blut, in Wagner's Handwörterbuch der Physiologie, Band i. S. 171) states that the difficulty of conducting a correct quantitative analysis of the fibrine of the blood is sufficient to account for these discrepancies.

† We refer those who may wish to obtain more detailed information upon this and some other points connected with the chemical differences between the arterial and venous blood, with references to the different authors who have investigated this subject, to Nasse's Treatise, entitled Das Blut, &c., and the article by him in Wagner's Handwörterbuch already referred to, and the first volume of Simon's Animal Chemistry, translated for the Sydenham Society, by Dr. Day.

‡ The Chemistry of Vegetable and Animal Physiology. Translated from the Dutch by Fromberg, Part II. p. 334.

blood, mentioned above. Michaelis *, and Marcet and Macaire †, in their ultimate or elementary analyses of both kinds of blood, found more carbon and less oxygen in venous, and less carbon and more oxygen in arterial blood; but Berzelius has adduced sufficient reasons to induce us to doubt whether, in such investigations, at least as at present conducted, the distinctive characters of the two kinds of blood can be preserved during the analysis, and that they are deserving of any confidence.‡

A larger quantity of fixed carbonic acid has been obtained from venous than from arterial blood by Mitscherlich, Gmelin, and Tiedemann.§

It is now placed beyond dispute that *free* gases exist in the blood, and it becomes a point of great importance in deciding upon the true theory of respiration to ascertain their nature, quantity, and relative proportions in the two kinds of blood. Four methods have been followed in procuring the free gases from the blood. 1. By the application of heat. 2. By the use of the air-pump. 3. By agitation of the blood with other gases. 4. By the respiration of other gases than atmospheric air.

The first of these methods is imperfect, as the albumen coagulates when the temperature is raised towards the boiling point, and may retain gases present in the blood. The second method is also liable to lead to negative results, unless the air-pump employed be of the best construction, for, according to Magnus, it is not until the pressure of the air within the bell-glass is reduced to one inch, that the gases begin to escape from the blood. In such experiments it is also necessary to employ blood from which the fibrin has been removed, for coagulated blood will retain the free gases, and prevent their escape.

Sir H. Davy stated that by raising the temperature gradually to 200 Fahr., he obtained from 12 cubic inches of the arterial blood of a calf $1\frac{1}{10}$ cubic inch of carbonic acid gas, and $\frac{7}{10}$ of a cubic inch of oxygen ‖; and that he procured carbonic acid gas from human venous blood heated to 112 Fahr.¶ Enschut assures us that, by subjecting blood to the temperature of boiling water, he obtained carbonic acid gas both from venous and arterial blood, and a greater quantity from the former than the latter kind of blood.* It is alleged that Brande obtained carbonic acid gas both from venous and arterial blood in considerable quantity by the use of the air-pump †; and Scudamore states that he procured it by the same means in variable quantities from venous blood.‡ Collard de Martigny § and Enschut ‖ procured carbonic acid gas both from venous and arterial blood, by placing them in the Torricellian vacuum, and a larger quantity from the former than from the latter. Nasse, sen.¶, Stevens**, Dr. G. Hoffman ††, Enschut ‡‡, Dr. Maitland §§, and Bischoff ‖‖, obtained carbonic acid gas from venous blood on agitating it with hydrogen, or by allowing this gas to stand over the blood for several hours. The existence of free carbonic acid gas in the blood was still, however, regarded by some physiologists as very problematical, since several trust-worthy and careful experimenters, such as Dr. J. Davy ¶¶, Mitscherlich, Gmelin,

* Diss. Inaug. de Partibus Constitutionis singularium Partium Sanguinis arteriosi et venosi. Berolini, 1827.

† Annales de Chimie et Physique, tom. li. p. 382. 1832.

‡ Lehrbuch der Chemie, Band iv. S. 99, 100. Dresden, 1831.

§ Zeitschrift für Physiologie, Band v. 1833. Mitscherlich, Gmelin and Tiedemann, by the addition of acetic acid, and the application of heat, obtained from 1000 parts of venous blood at least 12·3 parts, and from the same quantity of arterial blood 8·3 parts of combined carbonic acid.

‖ Beddoes' Contributions to Physical and Medical Knowledge, p. 132. 1799.

¶ Idem opus, p. 134.

* Dissertatio Physiologico-Medica de Respirationis Chymismo, p. 96 to 99. 1836. Enschut, in one set of experiments, obtained in this manner from 40 cubic centimètres (2·440 English cubic inches) of each kind of the blood of the calf, 2 to 4 cubic centimètres (·12205 to ·24410 English cubic inches) of carbonic acid gas from venous blood, and 1 to 2·5 cubic centimètres (·061025 to ·15256 English cubic inches) of the same gas from arterial blood, p. 99. Enschut points out various precautions necessary to be observed to secure accuracy in such experiments, a want of attention to which, he believes, was the cause of the failure of Dr. J. Davy, Müller, and others, in their attempts to obtain carbonic acid gas from blood by heat, p. 100—104.

† Sir Everard Home, in London Philos. Trans. vol. xxix. p. 172. 1818. It is stated by Sir Everard (p. 181), that Mr. Brande obtained carbonic acid in the proportion of 2 cubic inches for every ounce of blood,—a quantity so large, and obtained apparently with such facility, as to raise insuperable suspicions regarding the accuracy of the experiments. Sir Everard Home (29th vol. Philos. Trans. p. 189) and Scudamore state that they observed the escape of free carbonic acid gas from the blood during its coagulation,—an observation not confirmed by others. It appears that Vogel also obtained carbonic acid from venous blood by means of the air-pump. (Schweigger's Journal, Band xi. S. 401, as quoted by Bischoff.)

‡ An Essay on the Blood, p. 108. 1824. The largest quantity of carbonic acid gas that Scudamore procured from venous blood, was half a cubic inch of gas from six ounces of blood.

§ Magendie's Journal de Physiologie, tom. x. p. 127. 1830.

‖ Opus cit. p. 115.

¶ Meckel's Archiv, Band ii. 1816. Nasse allowed the hydrogen to stand over blood from 24 to 48 hours.

** Philos. Transact. vol. xlvi. p. 345. 1835.

†† Medical Gazette, for 1832—1833, vol. xi. p. 881.

‡‡ Diss. de Respirationis Chymismo, p. 124 to 126. Enschut obtained carbonic acid by this means also from arterial blood, but in smaller quantities than from venous blood.

§§ Experimental Essay on the Physiology of the Blood, p. 52. Edinburgh, 1837.

‖‖ Commentatio de Novis quibusdam Experimentis Chemico-Physiologicis ad illustrandam Doctrinam de Respiratione institutis, pp. 17, 18. Heidelberg, 1837. Bischoff also procured carbonic acid gas from arterial blood by means of the air-pump, pp. 11, 12.

¶¶ Philos. Trans. vol. xxxiv. p. 506. 1823.

and Tiedemann *, Stromeyer †, Müller and others ‡, failed in obtaining any carbonic acid gas from the blood by the air-pump and other means, and it was not until the publication of the important experiments of Magnus, confirmed as they have been to a certain extent by other observers, and strengthened by evidence collected both before and since on the results of the respiration of animals in hydrogen and nitrogen gases, that the existence of any free gas in the blood has been generally admitted. Bertuch and Magnus procured carbonic acid gas from human venous blood by agitating it with hydrogen.§ Magnus has not only obtained carbonic acid gas from both kinds of blood in some of the domesticated animals, but also oxygen and azote by means of the air-pump. The two latter gases were also procured from both kinds of blood by agitation with carbonic acid gas. The quantity of gases obtained from the blood by the air-pump in these experiments by Magnus amounted to $\frac{1}{10}$th, and sometimes to $\frac{1}{8}$th of the volume of the blood employed; but from the difficulty of liberating the gases from the blood, he believes that this quantity forms but a small part of that actually held in solution in this fluid. In some experiments with hydrogen, the quantity of carbonic acid obtained amounted to $\frac{1}{5}$th of the volume of the blood employed. The relative quantity of oxygen gas to the carbonic acid gas is greater in arterial than in venous blood. In venous blood the oxygen was as $\frac{1}{4}$th, and often $\frac{1}{5}$th, while in arterial blood it was at least as $\frac{1}{3}$d and sometimes $\frac{1}{2}$ to the carbonic acid.|| Magnus, in a second memoir on this subject, states that he obtained the following quantities of oxygen and nitrogen from the arterial blood of two old horses, by agitating it in carbonic acid gas: —

Oxygen.	Azote.	
10·5	2·0	per cent. of the volume
10	3·3	of blood employed.¶

By adding together the *total quantity* of gases collected from each kind of blood in his different experiments by means of the air-pump, and then comparing the relative proportions of their constituent parts, the following results are obtained: —

	Arterial blood.	Venous blood.
	Cubic centimètres.	Cubic centimètres.
Carbonic acid gas	39·5 or 62·3 per cent.	47·5 or 71·6 per cent.
Oxygen - -	14·7 — 23·2 —	10·1 — 15·3 —
Nitrogen * -	9·2 — 14·5 —	8·7 — 13·1 —

The quantity of oxygen gas procured from the blood of calves, oxen, and horses, previously agitated with atmospheric air, was not less than 10 per cent. and not more than 12 per cent. The blood can, however, absorb a greater quantity of oxygen and nitrogen than was collected in the experiments last-mentioned, for by repeatedly shaking blood with renewed quantities of carbonic acid gas to remove the whole of the oxygen and nitrogen gases it contained, and then agitating it in measured quantities of atmospheric air, he ascertained, by again measuring the atmospheric air, that the minimum quantity of oxygen absorbed amounted to 10 per cent., and the maximum to 16 per cent. The quantity of nitrogen procured in numerous experiments on the blood of calves, oxen, and horses, previously agitated with atmospheric air, was, when reduced to the temperature of 32 Fahr. and the mean barometric pressure, from 1·7 to 3·3 per cent. of the volume of the blood employed. The quantity of oxygen gas which blood is capable of absorbing from the atmospheric air, is, according to Magnus, from 10 to 13 times more than water can do under the same circumstances.† The experiments

* Loc. cit.

† Dissertatio Liberumne Acidum Sanguine contineter. Göttingen, 1831.

‡ Two at least of these experimenters, viz. Dr. Davy and Gmelin, have since satisfied themselves that carbonic acid gas is evolved from blood under the air-pump. Dr. Davy (Philos. Transact. for 1838, p. 291) obtained it in small quantities both from venous and arterial blood, and Gmelin (Preface to Bischoff's Commentatio de Novis quibusdam Experimentis, &c.) also in small quantity from venous blood.

§ Poggendorff's Annalen der Physik und Chemie, Band xl. S. 583. 1837.

|| Idem opus.

¶ Poggendorff's Annalen, Band lxvi. S. 202. 1845. Enschut had, previous to Magnus's experiments, obtained azote from both kinds of blood, and in greater quantity from venous than from arterial blood. Opus cit. p. 159.

* Poggendorff's Annalen, Band lxvi. S. 189. Gay Lussac (Annales de Chimie et de Physique, 3me série, tom. x. p. 1. 1844), has brought forward various objections against the inferences drawn by Magnus from his experiments. He asserts that they lead to the conclusion that more carbonic acid gas exists in arterial than in venous blood. Magnus has replied, and on the whole successfully, to these objections of Gay Lussac (Opus cit. Band lxvi). He contends that as the quantity of gases procured was only a part of what the blood actually contained, and as the experiments were of different duration, it must lead to error to compare, as Gay Lussac has done, the relative quantities of carbonic acid gas obtained from corresponding quantities of the two kinds of blood; and that the legitimate mode of procedure under the circumstances of the case, is to compare, as has been done in the above table, the relative quantities of the whole of the gases procured from each of the two kinds of blood.

† Poggendorff's Annalen, Band lxvi. S. 202. In some experiments the quantity of nitrogen absorbed by the blood, when previously agitated with carbonic acid, was 6·5 per cent. Though these various results obtained by Magnus in his experiments have not been fully confirmed by others, indeed several experimenters, such as Enschut, Bischoff, and Dr. J. Davy, who succeeded in procuring carbonic acid gas both from venous and arterial blood, failed in obtaining decided evidence of the presence of oxygen gas, yet they appear to have been so carefully and repeatedly performed, that a belief in their general

of Dr. J. Davy, Mitscherlich, Gmelin and Tiedemann, Enschut and Magnus, prove that venous blood can absorb considerably more than its own volume of carbonic acid gas; and according to Mitscherlich, Gmelin and Tiedemann, and Enschut, more of this gas can be absorbed by arterial than by venous blood.*

Lehmann has endeavoured to ascertain the relative quantities of free and combined carbonic acid in the blood. In twelve experiments upon bullock's blood the average quantity of free carbonic acid in 1000 grammes (15433·0 Troy grains) of blood, was 0·132 gram. (1·937 grains) of free, and 0·6759 gram. (10·431 grains) of combined carbonic acid: or, estimating these quantities by volume, in 61·250 English cubic inches of blood, there were 4·271 cubic inches of free, and 21·968 cubic inches of combined carbonic acid.†

The results obtained on causing animals to breathe gases devoid of oxygen are in unison with those derived from direct experiment, and furnish additional evidence in proof of the existence of free gases in the blood. That a quantity of carbonic acid gas may be exhaled from the blood during the respiration of gases devoid of oxygen is proved by the experiments of Spallanzani* and Dr. W. F. Edwards† on the products of the respiration of snails confined in hydrogen and azote; those of Dr. W. F. Edwards‡ on a fish (Cyprinus aureus) confined in water saturated with hydrogen; those of Dr. W. F. Edwards §, Collard de Martigny ||, Müller and Bergemann ¶, Bischoff** and Marchand ††, on frogs confined in hydrogen or azote; and those of Dr. W. F. Edwards ‡‡, upon the young of certain of the mammalia confined in hydrogen gas. The experiments of Nysten §§, in which he first exhausted the air, as far as possible, in the lungs of adult dogs, and then caused them to breathe hydrogen or azote; and those of Sir H. Davy ||||, and of Coutanceau and Nysten ¶¶, on the respiration of nitrous oxide and azote in their own persons, though not free from serious objections, are still, as far as they go, in favour of the opinion that free carbonic acid gas is contained in the blood.

In a former part of this article we have detailed several observations, both upon the human species and the lower animals, to prove that a quantity of azote is frequently exhaled in respiration. The experiments of Allen and Pepys ***, and Nysten †††, show that the exhalation of azote is considerably increased by breathing oxygen or hydrogen, or a mixture of these two gases, and thus afford additional evidence that free azote exists in the blood. Marchand concludes from his experiments on frogs, that when they are made to breathe pure oxygen gas, azote is evolved from the blood, and that when made to breathe pure hydrogen, both oxygen and azote are evolved from the blood.‡‡‡

Differences in the form of the red corpuscles in venous and arterial blood. — The physical

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accuracy is justly almost universally entertained by physiologists. Marchand (Journal für praktische Chemie, Band xxxv. S. 391) is the only other chemist, as far as we are aware, who has procured oxygen gas from the blood. He ascertained, by qualitative but not by quantative analysis, that oxygen gas is contained in the venous blood of the dog.

It has been argued, and the objection is anticipated and examined by Magnus, that part of the carbonic acid gas obtained from the blood in the above experiments may not have existed in the free, but in the combined state in the blood. It has been proved by the experiments of Heinrich Rose (Poggendorff's Annalen, Band xxxiv. S. 149. 1835), and Marchand (Journal für praktische Chemie, Band xxxv. S. 389, 390. 1845), that when a solution of bicarbonate of soda is agitated with, or even exposed for some time to, atmospheric air or hydrogen, it gives off part of its carbonic acid, and becomes a sesquicarbonate; and if heat be now applied, an additional quantity of carbonic acid is given off, and it is reduced to the state of carbonate of soda. If, therefore, bicarbonate of soda exists in the blood, part of the carbonic acid gas obtained in the experiments of Magnus and others may have been derived from this source. The exact condition of the carbonates of soda in the blood is not known: indeed their existence there has lately been called in question by Enderlin (Annalen der Chemie und Pharmacie, Band xlix. S. 317) and Liebig (idem opus, Band lvii. S. 126. 1846), but without sufficient reason, as Marchand (Journal für praktische Chemie, Band xxxvii. S. 321. 1846), Lehmann (idem opus, Band xl.), and Moleschott (Holländische Beiträge, Band i. hedft ii. S. 163. 1847) have shown.

* Dr. J. Davy (Philos. Transact. for 1838, p. 298) has made an important observation on the absorbing capacity of the blood for carbonic acid under different circumstances. In two animals, one of which was killed by strangulation, the other by exhaustion of the air of the lungs by the air-pump, the blood of the former absorbed only 150 per cent., that of the latter 370 per cent.

† Journal für praktische Chemie, von Erdmann und Marchand, Band xl. S. 133. 1847.

* Mémoires sur la Respiration, p. 346 to 351.

† De l'Influence des Agens Physique sur la Vie, p. 449. 1824.

‡ Opus cit. p. 447, 448.

§ Opus cit. p. 442 to 447.

|| Magendie's Journal de Physiologie, tom. x. p. 122 to 124.

¶ Muller's Elements of Physiology, translated by Baly, vol. i. p. 354.

** Commentatio de Novis quibusdam Experimentis Chemico-Physiologicis, p. 20.

†† Journal für praktische Chemie, Band xxxiii. S. 154. 1844. Marchand thinks that in the experiments of those who preceded him, upon the respiration of frogs in hydrogen, that the gas employed must have contained some oxygen, as the animals lived longer than those used in his experiments where the gas was quite pure.

‡‡ Opus cit. p. 453 to 455.

§§ Recherches de Physiologie et de Chimie Pathologiques, p. 225 to 229.

|||| Researches, Chemical and Philosophical. Division II.

¶¶ Coutanceau's Révision des Nouvelles Doctrines Chimico-Physiologiques, p. 280 to 302. 1821. Coutanceau and Nysten breathed azote alone; and their experiments were regarded, even by Coutanceau himself, as "essais bien incomplets." Opus cit. p. 301, 302.

*** Philos. Trans. 1809, p. 404.

††† Recherches, &c. p. 230, 231.

‡‡‡ Opus cit. Band xxxiii. S. 154—159. Band xxxv. S. 386—389. Marchand does not distinctly state that he ascertained this by direct analysis of the expired gases.

conditions of the red corpuscles can be changed by the action of various agents, such as pure water, and solutions of certain neutral salts. By the action of the former, the corpuscles swell, become more globular, and reflect less light; by the action of the latter, they become smaller, thinner, somewhat bent and notched, and reflect more light. These changes are apparently dependent upon endosmotic and exosmotic currents, between the fluid contents of the red corpuscles and the surrounding fluid. It has been maintained that the red corpuscles of venous and arterial blood differ in their external form, — the former approaching in their shape those acted upon by water, the latter those subjected to the action of solutions of the neutral salts; and this change in the form of the corpuscles has been adduced as the cause of the difference in colour between arterial and venous blood. Kaltenbrunner *, Schultz †, H. Nasse ‡, Scherer §, Reuter ||, Mr. Gulliver ¶, and Harless **, have described various differences in the external form of the red corpuscles of the two kinds of blood, as observed by them under the microscope, from which some of them infer an increase in their power of reflecting light ††; while Burdach ‡‡, Müller §§, Bruch ||||, and Marchand ¶¶, have failed in detecting by the microscope any difference in their external form in the two kinds of blood.*** Those observers who have described differences in the shape of the red corpuscles in arterial and venous blood do not quite agree in their account of these. They agree, however, in this, that the red corpuscles are more turgid and less clear in venous than in arterial blood. Scherer describes the red corpuscles in arterial blood as biconcave, and those in venous blood as biconvex and decidedly swollen. Mr. Gulliver states that in all his experiments "the red corpuscles were reduced in size, both in breadth and thickness, by neutral salts, and in a less degree by sugar and oxygen; while the first effect of water and of carbonic acid was to swell the corpuscles and make them more globular." Nasse says that the red corpuscles of the arterial blood in the mammalia, on the contact of carbonic acid gas, become muddy in the middle, the ring formed by the colouring matter becomes broader, they become darker and somewhat thicker, at least on one side, and they adhere closer together. Harlass gives measurements of the corpuscles of the blood of the frog, when brought into contact with oxygen and carbonic acid, to show that they become somewhat broader and thicker when exposed to the action of the latter gas. He also states that while the corpuscles in the former are finely granulated on the external surface, those in the latter are smooth.

Theory of respiration. — The actions between the blood and the atmospheric air in the performance of the function of respiration are regulated entirely by chemico-physical laws. No doubt the blood and air are conveyed to and from the lungs through the instrumentality of the vital properties of the nervous and muscular tissues, but the changes they there undergo do not appear to be influenced by vitality. When venous blood and atmospheric air are brought into contact out of the body, the same actions apparently occur as in the lungs during life, viz., the atmospheric air loses part of its oxygen, acquires in its place a quantity of carbonic acid gas, and the blood assumes the arterial hue. The distribution of the blood in innumerable minute streamlets upon the surface of the air-cells, filled with atmospheric air, affords much more advantageous means than can be obtained in experiments out of the body, for facilitating the mutual actions of the blood and atmospheric air. From the known rapidity with which gases permeate both living and dead animal membranes, the moist delicate membranes that intervene between the blood contained in the capillaries of the lungs, and the atmospheric air in the air-cells, will readily permit the endosmose of a portion of the atmospheric air, and the exosmose of a portion of the gases held in solution in the blood.

The rest of our remarks on the theory of respiration may be arranged under three heads: viz. 1st, the manner in which the air in the upper and in the lower parts of the respiratory apparatus is intermixed; 2dly, the nature of the immediate actions between the blood and atmospheric air in the lungs, in which a quantity of carbonic acid gas appears in the expired, and a quantity of oxygen disappears from the inspired air; 3dly, the nature of the changes the blood undergoes in passing from the venous to the arterial condition.

* Experimenta circa Statum Sanguinis et Vasorum in Inflammatione, p. 71. 1826.

† Das System der Circulation, S. 27. 1836.

‡ Handwörterbuch der Physiologie, von Wagner, Band i. S. 97. 1842.

§ Zeitschrift Für Rationelle Medizin. Herausgegeben von Henle und Pfeufer, Band i. heft ii. S. 288. 1843.

|| Idem opus, Band iii. heft ii. S. 165. 1845.

¶ Work of Hewson, printed for the Sydenham Society, note at p. 9. 1846.

** Monographie über den Einfluss der Gase auf die Form der Blutkörperchen, von Rana temporaria. Erlangen, 1846.

†† We have not included, for obvious reasons, among these authorities in favour of there being a difference in the shape of the red corpuscles in the two kinds of blood, those authors who, like Henle and Mulder, have adopted this view without stating that they had personally investigated by the microscope the point at issue.

‡‡ Traité de Physiologie, &c. traduit par Jourdan, tom. vi. p. 135, 136. 1837.

§§ Elements of Physiology, translated by Baly, vol. i. p. 346. 1840.

|||| Zeitschrift, &c. Von Henle und Pfeufer, Band i. heft iii. S. 440. 1844; Band v. heft iii. S. 440. 1847.

¶¶ Journal für praktische Chemie, Band xxxviii. S. 279. 1846.

*** Dr. G. O. Rees (Med. Gazette, Session 1844-5, p. 840) maintains that the structure of the red particles prevents the possibility of their assuming any other form than the biconcave in a fluid of the specific gravity of serum, whether exposed to air or not; but this statement appears to be founded upon the presumed effects of the endosmotic and exosmotic conditions of the red corpuscles, and not upon any examination by the microscope of the effects of gases upon these bodies.

On the manner in which the air in the upper and lower parts of the respiratory apparatus becomes intermixed.—The respiratory qualities of the other parts of the inner surface of the air-passages must be very feeble when compared with the membrane of the air-cells of the lungs; and there can be no doubt that almost all the carbonic acid present in the expired air is derived from the blood circulating in the capillary blood-vessels of the air-cells; and that this evolution of carbonic acid gas is continuous, going on during expiration as well as during inspiration. As a portion only of the atmospheric air, probably not much more than a fourth or a fifth part, is renewed at each ordinary respiratory movement when the body is in a state of rest, the air expelled during expiration will chiefly consist of that occupying the larynx, trachea, and the larger bronchial tubes; so in the same manner, the air drawn in by inspiration will chiefly occupy the same parts of the respiratory apparatus. It is well known that the air expelled in the first part of an expiration contains less carbonic acid than that expelled towards its close; thus the air in the deeper parts of the respiratory apparatus must be richer in carbonic acid and poorer in oxygen than that in the upper parts. The amount of intermixture of the gases in the different parts of the respiratory apparatus effected by the muscular movements of the chest would, in all probability, be too imperfect for the proper arterialisation of the blood, were this not aided by the well-known tendency of gases to diffuse themselves through each other. As the air in the air-cells differs from that in the higher parts of the respiratory apparatus in containing more carbonic acid and less oxygen, the nitrogen being nearly the same in both, this diffusion of gases is probably chiefly confined to the two former. From the oxygen being of lighter specific gravity than the carbonic acid gas, the descending current of oxygen gas will exceed the ascending current of carbonic acid, and 81 parts of carbonic acid will be replaced by 95 of oxygen, for according to the law regulating the diffusion-volumes of gases under such circumstances, established by Graham, in the case of each gas this is inversely proportional to the square root of its density.*

On the nature of the actions between the blood and the atmospheric air in the lungs, by which a quantity of oxygen is removed from the inspired air, and a quantity of carbonic acid gas added to the expired air.—Four views have been maintained on this point.—1. That of Lavoisier, La Place, and others; that the oxygen which disappears from the inspired air unites directly in the lungs with hydro-carbon furnished by the venous blood, and forms the carbonic acid gas and watery vapour that escape along with the expired air.†

2. That of La Grange and Hassenfratz; that free carbonic acid gas is present in a state of solution in the venous blood before it arrives at the lungs, where this gas is exhaled; that nearly the whole of the oxygen gas abstracted from the inspired air is absorbed at the lungs, and held in solution by the arterial blood; and that the combination of the oxygen with the carbon and formation of carbonic acid chiefly take place when the blood is passing through the capillaries of the systemic circulation.*

3. That the oxygen that disappears from the inspired air enters into chemical combination with one or more of the constituent parts of the blood in its course through the lungs, that in the passage of the blood through the capillaries of the systemic circulation this oxygen leaves the substance or substances to which it had united itself, and combines with carbon to form carbonic acid, or with carbon and hydrogen to form carbonic acid and water, and that the carbonic acid thus formed does not combine chemically with any of the constituent parts of the venous blood, but is held in solution by it, and is evolved while passing through the capillaries of the lungs.

4. That not only the oxygen that disappears from the inspired air is united chemically in the arterial blood, but also the carbonic acid formed during its circulation through the systemic capillaries enters into chemical combination with some one of the constituent parts of the venous blood; that the combination thus formed is decomposed in the pulmonic capillaries by the agency of the absorbed oxygen, and the carbonic acid thus set free is evolved and escapes in the expired air.

The first view, viz. that the carbonic acid that appears in the expired air is formed in the lungs by the combination of part of the oxygen of the inspired air with the carbon of the venous blood, must now be regarded as untenable. The existence of free gases in the blood, the evolution of carbonic acid from the blood at the lungs in animals made to breathe gases devoid of oxygen, the small increase of

* Edinburgh Transactions of Royal Society, vol. xii. p. 573. 1834.

† Seguin and Lavoisier "Sur la Transpiration des Animaux," in Mémoires de l'Académie des Sciences for 1790, p. 601. It is still maintained by some chemists and physiologists, who appear to regard the function of respiration simply as a process of combustion, but who do not uphold the opinion that this combustion takes place in the lungs and that the watery vapour in the expired air is immediately derived from this source, that a part of the oxygen that disappears from the inspired air unites with hydrogen to form water. No satisfactory evidence is offered in support of this opinion, and in the present state of our knowledge it must be regarded as a mere conjecture.

* This doctrine, as propounded by Hassenfratz (Annales de Chimie, tom. ix. p. 261. 1791), which has received various modifications since his time, was based on the view that the purple colour of the venous blood is the result of the combination of oxygen with the carbon and hydrogen of the blood, while the scarlet colour of arterial blood is caused by the solution of oxygen gas in it, and consequently there can be little combination of the carbon and hydrogen of the blood with the atmospheric air in the lungs.

temperature the blood acquires in its change from the venous to the arterial condition*, and the result of observations made upon the blood out of the body, when subjected to alternate applications of oxygen and carbonic acid gas, are all opposed to the supposition that the formation of carbonic acid gas takes place to any great extent in the lungs. The existence of a quantity of free carbonic acid in the venous blood, more than sufficient to furnish the whole of this gas thrown off at the lungs, and the avowedly conjectural explanation of the manner in which the carbonic acid is combined and the agency by which its combinations are decomposed in the lungs, given by those who advocate this view, justify the adoption of the opinion that the carbonic acid gas evolved at the lungs exists in a free state in the venous blood before it reaches the lungs.

An interchange, therefore, takes place between the air in the cells of the lungs and the blood in the pulmonic capillaries, the latter receiving oxygen and giving up part of the free carbonic acid held by it in solution. These gases, from their solubility, readily permeate the thin moist membranes interposed between the blood and the atmospheric air contained in the cells of the lungs. We have already mentioned that Valentin and Brunner have concluded from their experiments that this interchange of oxygen and carbonic acid gas is regulated by the law of the diffusion of gases established by Graham; but besides the objections that may be urged against this view, drawn from the considerable diversity in the relative proportions of these gases interchanged during respiration as ascertained by different experimenters, the conditions under which the two gases are placed in respiration are very different from those in the experiments instituted by Graham.† In respiration the gases are separated by moist animal membranes, and one of these, viz. the carbonic acid, is held in solution in a fluid subjected to an increased pressure caused by the action of the heart.*

We are not, in the present state of our knowledge, in a condition to form any thing like an accurate estimate of the various circumstances which regulate this interchange between the oxygen of the air and the carbonic acid gas of the blood, but it is obvious that it will be affected in a most important manner by the relative proportion of these gases in the air contained in the air-cells of the lungs and in the blood, and by the quantities of atmospheric air and blood transmitted through the respiratory apparatus.

We have seen, from the experiments of Vierordt, that when the air is rapidly renewed in the lungs, though the percentage of carbonic acid in the expired air is diminished, yet the total amount of this gas thrown off from the lungs within a given time is proportionally increased; while, on the other hand, when the respirations are diminished below the natural standard, though the percentage of carbonic acid in the expired air is increased, yet the total quantity thrown off from the lungs in a given time is proportionally diminished. When the atmospheric air in the lungs is rapidly renewed by an increased frequency of the respiratory movement, the diffusion of the oxygen in the higher, and of the carbonic acid in the deeper, parts of the air tubes will proceed more rapidly, and the air in the deeper parts or in the air-cells will contain a less percentage of carbonic acid, and a greater percentage of oxygen, than when the respirations are carried on with the usual frequency and force. This diminution of the usual quantity of carbonic acid gas and increase of oxygen in the deeper parts of the lungs will accelerate the interchange between the oxygen of the air and the carbonic acid of the blood, provided the blood holds its normal amount of free gases in solution, and a larger quantity than usual of carbonic acid will be separated from the blood at

* Dr. J. Davy ascertained (Lond. Philos. Trans. for 1838, p. 298) that oxygen gas shaken with venous blood out of the body raised the temperature of the latter from 1° to 2° Fahr. Marchand (Journal für praktische Chemie, Band xxxv. S. 400) adduces reasons for believing that this increase in temperature arose from the mere absorption of the gas, and not from any chemical action between it and the blood.

† Graham's first experiments, from which he deduced his law that "the diffusive velocities of different gases are inversely as the square root of their densities," were made by interposing a porous septum of stucco between the gases experimented upon and the external air. The equivalent diffusion-volumes of oxygen and carbonic acid calculated according to this theory, with which the experimental results closely agree, are — air being equal to 1, oxygen 0·9487, and carbonic acid 0·8091. (Transactions of Royal Society of Edinburgh, vol. xii. p. 222. 1834.) In some later experiments Mr. Graham ascertained that this law also held when gases pass through minute apertures in a thin plate into a vacuum, while, on the other hand, the discharge of the same gases through tubes into a vacuum has no uniform relation to the density of the gases. (Philosophical Transactions of London for 1846, p. 373.)

* The passage of gases through moist membranes is not simple diffusion, as it is influenced by the solubility of these gases in the fluids of the membranes. In the case of respiration it will also probably be affected by the attractive force of the constituents of the blood for the gases. The relative rapidity of the passage of different gases through membranous septa, as observed in the experiments of Dr. Faust and of Mr. Mitchell (American Journal of the Medical Sciences, Nov. 1830), and by other experimenters, is not in accordance with the law of the diffusion of gases, as determined from experiments upon their diffusive velocities through porous septa into the atmospheric air, and through minute apertures in a thin plate into a vacuum. When a bladder filled with oxygen gas is introduced into a vessel full of carbonic acid gas, the latter passes so much more rapidly through the coats of the bladder than the former, that the bladder becomes gradually distended, and at last may burst. In these last experiments, equally as in those of Graham, the conditions under which the diffusion of the gases occurs, are not the same as those in respiration; and we find the carbonic acid gas passing in greater quantity through the organic membranes than the oxygen,— the reverse of what takes place in respiration.

the lungs, and carried out in the expired air. If, then, we add an increased flow of blood through the capillaries of the lungs to an increased frequency of the respiratory movements, as occurs in exercise, the interchange between the oxygen of the air and the free carbonic acid of the blood will be carried on with greater activity. When, on the other hand, the air is renewed in the lungs less frequently than usual, as happens when the respiratory movements are diminished in number and in extent, the air in the deeper parts of the lungs will contain less oxygen and more carbonic acid than usual, and the interchange between the oxygen of the atmospheric air and the free carbonic acid of the blood will proceed more slowly. When the respirations are reduced to about one half of their normal frequency, as occurs in the course of some diseases, and after division of the vagi nerves, the carbonic acid gas gradually accumulates in the blood, less oxygen is absorbed, and the individual generally sooner or later dies of asphyxia. When the quantity of carbonic acid gas in the air-cells reaches a certain amount, the evolution of this gas from the blood will cease; and when this is carried still farther, there will be an absorption of a part of the carbonic acid gas by the blood.

The interchange between the nitrogen and the other gases at the lungs is very small in the normal condition of the respiration, but there is every reason to believe that this is regulated by circumstances similar to those which determine the interchange of the oxygen and carbonic acid. The nitrogen is much less soluble in the blood than the oxygen and carbonic acid, and we presume that its power of permeating moist animal membranes is much inferior to these gases, and that the smaller quantity of it held in solution in the blood may be in this manner explained. We have already pointed out that, in the experiments made to determine whether nitrogen is absorbed or exhaled at the lungs, opposite results have been obtained, but that the evidence preponderates in favour of the opinion that a small quantity of this gas is evolved from the blood during respiration. By an alteration of the usual relation between the quantities of nitrogen present in the air and in a free state in the blood, the evolution of nitrogen from the blood may be increased or suspended, or it may be absorbed by the blood instead of being evolved by it. In a previous part of this article we have referred to experiments which prove that when animals breathe oxygen or hydrogen gases, or a mixture of both, azote is evolved in greater quantity than usual from the blood in the lungs; and that when they breathe azote alone, part of this gas is absorbed at the lungs.

The exact condition in which the whole of the oxygen absorbed at the lungs exists in the blood, notwithstanding the light thrown upon this point by recent researches, is still not free from considerable difficulties. Previous to the experiments of Magnus upon the gases of the blood, already referred to, the opinion of Le Grange and Hassenfratz, that the greater part of the oxygen gas absorbed at the lungs is dissolved in the blood and carried along with it in that condition to the systemic capillaries, was considered untenable by many celebrated physiologists, the more especially as the attempts to detect free oxygen in the arterial blood had failed in all the more trust-worthy experiments. Different opinions as to the kind of chemical combination formed by the oxygen in the arterial blood have been entertained by those who believe that the portion of this gas that disappears from the inpired air does not unite with carbon in the lungs to form carbonic acid, and that little or none of it is simply dissolved in the arterial blood. In the greater number of these hypotheses, however, the oxygen is supposed to unite itself in whole or in part to the red corpuscles, and especially to the iron contained in these: and as the exact state in which the metal exists in the red corpuscles is still undetermined, this has given rise to very different notions regarding the changes effected upon it by the oxygen. According to other views, the oxygen in whole or in part is united chemically to some of the other constituent parts of the arterial blood, and from these it is again separated in passing through the systemic capillaries, and unites with carbon to form carbonic acid.*

* We shall here very shortly notice a few of the more recent theories of respiration, which proceed on the supposition that the oxygen abstracted from the inspired air is combined, in whole or in part, with some of the constituents of the arterial blood. Gmelin, Tiedemann, and Mitscherlich (Zeitschrift für Physiologie, Band v.) supposed that the oxygen absorbed at the lungs partly unites with carbon and hydrogen to form carbonic acid and water which are there exhaled, and partly with organic substances in the blood to form acetic and lactic acids; that these acids decompose some of the carbonates of soda brought to the lungs in the venous blood, and that the carbonic acid thus set free is also exhaled. The arterial blood in its course through the tissues, more especially those of the kidneys and skin, loses part of its acetic and lactic acids; and the soda with which they were combined, being set free, unites with the carbonic acid formed during the process of nutrition, and these carbonates are again decomposed in the lungs in the manner described. Dumas (Statique Chimique des Etres Organisés, pp. 43, 44, 3me édit.) believes that the absorbed oxygen combines with certain matters of the blood and forms lactic acid, the lactic acid combines with soda to form lactate of soda, and this latter salt, by a real combustion, is converted into carbonate of soda, which is decomposed in its turn in the lungs by a fresh portion of lactic acid. Liebig (Organic Chemistry of Physiology and Pathology, edited by Gregory, p. 265. 1841) supposes that carbonate of protoxide of iron exists in the red corpuscles of venous blood, and that in its passage through the lungs, a large portion of the absorbed oxygen unites with it, forms hydrated peroxide of iron, and sets the carbonic acid free. Mulder (The Chemistry of Vegetable and Animal Physiology, translated by Fromberg, Part II. p. 337) affirms that an alternate change into carbonate of the protoxide of iron and peroxide of iron in respiration is impossible, and maintains that the absorbed oxygen combines with the proteine compounds of the blood and forms oxy-proteine, which being conveyed by the

The presence of a larger quantity of free oxygen gas in the arterial blood than what is sufficient to form the carbonic acid gas evolved at the lungs, amounting in some cases to rather more than 10 per cent. of the volume of the blood in the experiments of Magnus, naturally leads to the conclusion that the greater part, at least, of the absorbed oxygen is not chemically combined in the arterial blood, and is simply held in solution by it. We are not, however, quite prepared to concur in the opinion of Magnus, that the *whole* of the absorbed oxygen is held in solution in the arterial blood, and that an interchange between part of the free carbonic acid of the venous blood, and part of the oxygen of the atmospheric air, embraces the entire changes in the blood as it passes from the venous to the arterial condition: for, if the opinion be correct that the elaboration of the materials of the chyle into blood is completed in the lungs, and that certain marked differences in the fibrin of the two kinds of blood, noticed above, really exist, something more than this is probably necessary. Though the experiments of Marchand appear to prove that the absorbed oxygen does not enter into any chemical combination with the constituent parts of the arterial blood in the lungs, by which carbonic acid gas is formed; yet, while the greater part of the absorbed gas is held in solution in the arterial blood, a small portion of it may enter into chemical combination in a manner hitherto not definitely ascertained.*

It is almost universally believed that the free carbonic acid gas in the blood is formed by the combination of the absorbed oxygen with carbon in the blood, chiefly if not entirely in the course of its circulation through the systemic capillaries; but this opinion, however plausible it may appear, and though it apparently accounts for the evolution of animal caloric in a satisfactory manner, does not rest upon any direct evidence. There are no facts that militate against the existence of such a combination, and there can be no doubt that in the present state of our knowledge it affords the readiest and most complete interpretation of the phenomena referred to it, but still it is quite possible that the carbonic acid may be formed during the process of nutrition differently from what is generally supposed.

Cause of the change of colour in the blood. — The manner in which the changes of colour in the blood is effected as it passes through the pulmonic and systemic capillary vessels, has not yet been satisfactorily determined. It seems now to be pretty generally admitted that the hæmatosine or colouring matter of the blood is enclosed within the enveloping membrane of the red corpuscles; that this hæmatosine, though it may be combined with iron, does not derive its colour from the presence of this metal; and that all attempts to explain the change in the colour of the blood in the lungs by the formation of certain oxides and salts of iron must be abandoned. It is well known that various substances, besides oxygen gas, can impart a bright red colour to venous blood when mixed with it, and without being attended with any evolution of carbonic acid gas. The best known of these are solutions of the sulphate of soda, nitrate of potass, phosphate of soda, carbonate of soda, carbonate of potass, and sugar.

The opinion of Stevens *, that the change from the venous to the arterial hue in the blood is to be attributed to the actions of the salts dissolved in the blood upon the hæmatosine, after the removal of the free carbonic acid of the venous blood through the attractive force of the oxygen of the atmospheric air, has not been confirmed by subsequent researches. It has been ascertained that the removal of carbonic acid from venous blood, by means of the air-pump †, or by agitation

arterial blood to the capillaries is decomposed during the nutritive processes, and carbonic acid is formed and held in solution in the blood.

[Dr. G. O. Rees has lately put forward the following ingenious theory of respiration. He finds by analysis that the corpuscles of venous blood contain fatty matter in combination with phosphorus, which does not exist in arterial blood, or, at most, is found in it only in very small quantity. In respiration the oxygen of the inspired air unites with this phosphorus and fatty matter, and a combustion of it takes place, of which the products are water and carbonic acid, from the union of the oxygen with the elements of the fatty matter, and phosphoric acid, from the union of the oxygen with the phosphorus. The carbonic acid and water are exhaled, and appear in the expired air; the phosphoric acid attracts the soda of the liquor sanguinis from its combination with albumen and lactic acid, and thus forms a tribasic phosphate of soda, a salt which possesses in a marked degree the property of giving a bright colour to hæmatosine. See Dr. Rees' paper in the Lond. Edin. and Dubl. Phil. Mag. for July, 1848. — Ed.]

* Marchand (Journal für praktische Chemie, Band xxxv. S. 385. 1845) in his experiments found that oxygen gas does not unite with fibrin to form carbonic acid until it has been exposed to its action for some days, in fact not until it is passing into a state of putrefaction; and that, on subjecting to a continuous current of oxygen gas, the red corpuscles, and beaten venous blood, after all the free carbonic acid held in solution had been carefully separated by the air-pump and agitation with hydrogen, no carbonic acid gas was evolved. These experiments invalidate the inferences in favour of the opinion, that the oxygen absorbed at the lungs partly enters into combination with the constituents of the blood in the lungs and forms or liberates carbonic acid gas, drawn from the experiments of Scherer (Annalen der Chemie und Pharmacie, Band xl. 1841) upon the action of oxygen gas upon fibrin, and those of Berzelius (Lehrbuch der Chemie, Band iv. S. 94. 1831), and Maack (De Ratione quæ Colorem Sanguinis inter, &c., p. 35. Kiliæ 1834) upon the greater absorbing power for oxygen of the colouring matter of the blood over the serum. Mulder (Holländische Beiträge, &c. Band i. heft i. B. 20. 1846) adduces various arguments to show that the experiments of Magnus, and they apply equally to those of Marchand, by no means prove that a part of the oxygen absorbed at the lungs does not enter into chemical combination with the constituents of the blood before it reaches the capillaries of the systemic circulation.

* London Philos. Transact. vol. xlvi. p. 345. 1835.

† Dr. J. Davy and others.

with hydrogen gas * and the addition of a saline solution, of the same strength as that existing in the blood †, will not impart to it the arterial hue, if oxygen gas be not at the same time present. The oxygen gas, therefore, acts directly, and not indirectly by removing the carbonic acid, in changing the colour of the blood; but as a small quantity only of this gas is sufficient, when the salts are present in their usual quantity, to produce this effect ‡, the action of the oxygen, in changing the colour of the blood in respiration, will be aided by the presence of the salts.

In the present state of our knowledge, there is some difficulty in deciding whether the reddening of the blood by the absorbed oxygen be entirely a physical action, or whether it be partly physical and partly chemical, seeing that several accurate observers, who have recently investigated this point, have arrived at very different conclusions.

The opinion, first promulgated by Dr. Wells §, that the change from the venous to the arterial hue arises from an increased reflection of light in the red particles, caused by the presence of the absorbed oxygen, and without any chemical change upon the hæmatosine, has of late obtained several supporters. Those who have adopted this view do not, however, agree in their explanation of the manner in which this increased reflection of light is effected; some maintaining that it arises from an alteration in the form of the red corpuscles, and that this change consists in the biconvex corpuscles of the venous blood, becoming biconcave in the arterial blood ‖; while others believe that the action of the oxygen on the blood is analogous to that of the nitrous oxide on the solutions of the salts of iron, changing their colour without entering into chemical union with them.*

We may, in the meantime, conclude that the change in the blood from the venous to the arterial hue in the lungs, is a physical and not a chemical action; and that though there is pretty strong evidence in favour of the opinion that this physical change consists in an alteration of the form of the red corpuscles, yet it is not free from doubt.

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* Bischoff, Dr. Maitland, Nasse, and Marchand.

† Gregory and Irving (vide London Medical Gazette, vol. xiii. p. 814. 1834). Nasse (Wagner's Handwörterhuch, &c., Band i. S. 182) affirms that even concentrated solutions of muriate of soda, nitrate of potassa, and carbonate of potass, cannot impart the true arterial hue to venous blood, without the presence of a small quantity of oxygen; and that when Stevens saw the blood redden under the air-pump, there must have been sufficient oxygen still present in the rarefied air to act on it with the aid of the salts.

‡ Nasse (opus cit. p. 182). He also infers from his experiments that oxygen can redden the blood without the presence of salts (p. 187).

§ London Philos. Transact. for 1797, p. 416.

‖ Scherer, Reuter, and Gulliver. Mulder (The Chemistry of Animal and Vegetable Physiology, p. 341, 342.) also contends that the arterial hue depends upon the red particles assuming the biconcave form and reflecting more light, but he gives a very different explanation of the cause of the change in the form of the red particles from the other supporters of this view. According to Mulder, part of the oxygen absorbed unites with some of the proteine compounds in the blood in the lungs, and forms oxyproteine, and this furnishes a thin envelope to the red corpuscles, and by its contraction causes them to assume the biconcave form. This opinion is supported neither hy direct ohservation nor by experiment. Marchand (Journal für praktische Chemie, Band xxxviii. § 276, 277) and Dumas (Comptes Rendus for 1846, tom. xxii. p. 900) after separating the red corpuscles from the other constituents of the blood, and washing them in a solution of sulphate of soda, found that they still ehanged from the venous to the arterial colour on the additiou of oxygen. Dumas concludes, that neither the presence of albumen nor fibrin is necessary to enable oxygen to redden venous blood; and Marehand, after a careful experimental investigation, affirms that the supposition that the changes of colour in the blood are from a chemical action, is attended with insuperable difficulties (opus cit. Band xxxviii. S. 278).

* Magnus aud Marchand.

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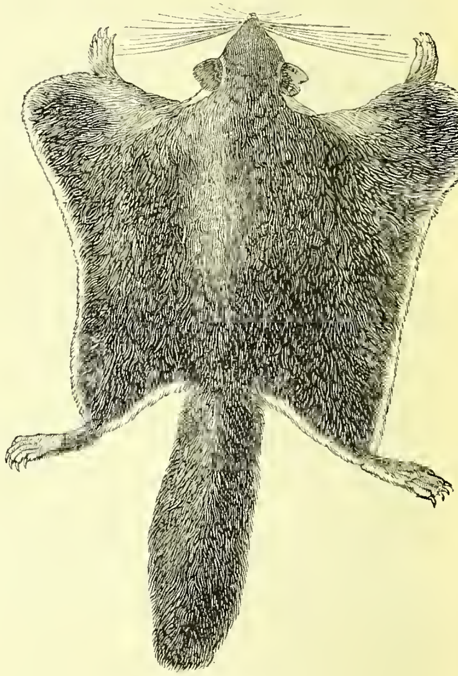
(*John Reid.*)

RODENTIA (*Glires*, Linn.) (Fr. *Rongeurs*). — An important order of mammiferous Vertebrata, distinguishable by the remarkable structure of their incisor teeth, which are adapted to perform the office of chisels by cutting and gnawing away the hard vegetable substances, which form their principal food. The animals of this order, indeed, appear to be specially appointed to devour the hardest substances, generally living upon the wood and bark of trees, as well as upon nuts and other shelled fruits. The incisor teeth, which characterize the animals of this order, are situated in both jaws, and are separated from the molar by a considerable space, so that they are ill-adapted to seize living prey, or to devour flesh, notwithstanding that certain genera of rodents exhibit decidedly carnivorous propensities. These incisors, also called *dentes scalprarii*, are only provided with enamel upon their anterior surface, so that the posterior portion of the tooth being worn away more rapidly than the anterior, these teeth always present a chisel-like edge. The lower jaw is articulated to the cranium by a longitudinal condyle, in such a manner that it has no horizonal motion except from before, backward, and *vice versâ;* a movement adapted to effect the act of gnawing. The molar teeth have their crowns flattened and traversed by plates of enamel, arranged transversely, the better to antagonise the backward and forward movement of the jaws.

Fig. 247.



Pteromys volitans.

Those genera in which these layers of enamel are simple plates, and which have the crowns of their molar teeth very flat, are more particularly frugivorous; those in which the eminences of these teeth are divided into blunt tubercles, are omnivorous; whilst a small number of genera, which possess pointed molars, will attack other animals, and in some of their habits approximate the Carnivora.

This order comprises the following genera: —

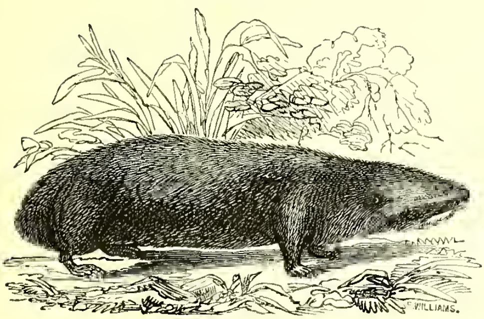
Sciurus (Squirrel). Pteromys (Flying Squirrel) (*fig.* 247.). Cheiromys (Aye-Aye). Arctomys (Marmot). Myoxus (Dormouse). Echimys. Hydromys. Capromys. Mus (Rat). Gerbillus. Meriones. Cricetus (Hamster). Arvicola (Vole). Fiber (Musk Rat). Georychus (Lemming). Otomys. Dipus (Jerboa) (*fig.* 248.). Pœphagomys. Helamys. Spalax (Rat Mole) (*fig.* 249.) Bathiergus (Cape Mole) (*fig.* 250.). Geomys. Diplostoma. Castor (Beaver). Myopotamus (Coui). Hystrix (Porcupine). Lepus (Hare). Lagomys (Rat Hare). Hydrochœrus (Capybara). Rhyzomys. Cavia (Guinea Pig). Dasyprocta (Agouti). Cœlogenys (Paca). Chinchilla.

Fig. 248.

Dipus hersipes.

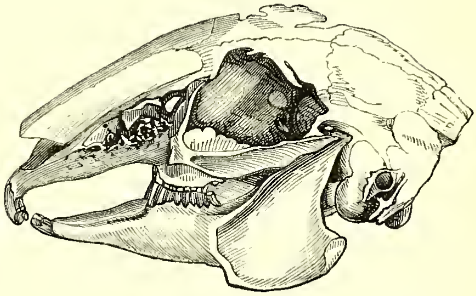
Bones of the cranium.— The bones of the cranium in the Rodentia present several peculiarities in their arrangement, which it will be necessary to notice.

Fig. 249.



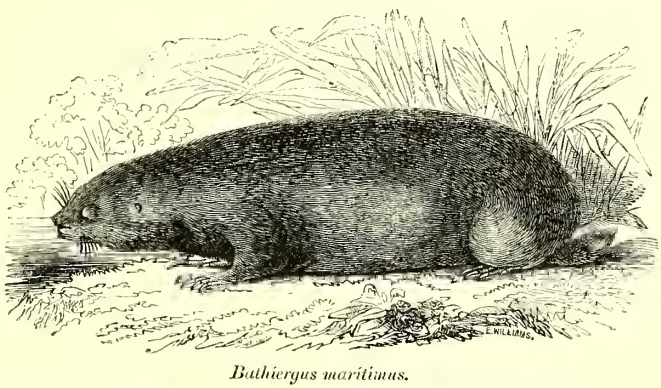
Spalax typhlus.

Fig. 251.



Skull of the Hare.

Fig. 250.



Bathiergus maritimus.

In the hare*, the anterior sphenoid is very remarkable, inasmuch as the two optic foramina are united into one, in front of which the sphenoid forms a single vertical lamella, an evident approximation to what is found in birds.

The os frontis presents a strong supra-orbital crest, which is deeply notched both before and behind. It advances on each side

* Cuvier, Anatomie comparée, last edition.

by a long process, between the ascending point of the inter-maxillary bone and that portion of the maxillary which forms the cheek : the parietals remain for some time distinct from each other, and from the inter-parietal; which latter, in the *rabbit*, is small, and resembles an ellipse placed transversely : in the hare this last bone can only be detected in very young specimens, when it is found to consist of two small pieces, which are separated by a prominent angle of the occipital. The petrous portion of the temporal bone occupies a large triangular space in the occipital region of the skull. The mastoid process is entirely formed by the occipital bone; but the os petrosum furnishes a parallel process, which embraces the temporal externally, and at an early period it becomes united therewith. The tympanic portion of the temporal is considerably arched, but is far from reaching the pterygoid processes. The temporal alæ of the posterior sphenoid do not mount up very high, and do not reach the frontal, from which they are separated by the anterior sphenoid and by the temporal, still less do they approximate the parietal bones, which do not descend so low as the temporal.

In the *marmot*, the frontal and the parietal bones are at a very early age consolidated into a single piece, and an inter-parietal bone is not discoverable even in very young marmots. The frontal bones, which are extensively penetrated by the two ossa nasi, penetrate deeply between the parietals, which latter are narrow, and the sutures which connect them to the temporal remarkably straight and parallel. The occipital suture is situated a little in front of the occipital crest, with which it runs nearly parallel.

One-third of each side of this crest is formed by the petrous bone, which infringes slightly upon the occipital surface of the cranium. External to the tympanum, and a little behind it, there is a mastoid process ; behind which is another (the paramastoid), formed by the occipital bone. The tympanic bones are round and much inflated ; they are consolidated at an early age with the petrous bones. In the temple the posterior sphenoid mounts considerably upwards, but nevertheless only joins the temporal and the frontal, the parietal not descending sufficiently low. The orbital ala of the sphenoid enters but little into the composition of the orbit.

In the *squirrel* the separation between the parietals and the frontal bones is likewise obliterated at a very early period. The inter-parietal also becomes soon confounded with the parietal; but in very young subjects its presence is well-marked; it is of semi-circular form. There is, moreover, a special point of ossification in the centre of the cross, formed by the frontal and parietal bones. The glenoid cavity is more deeply excavated than in the marmot.

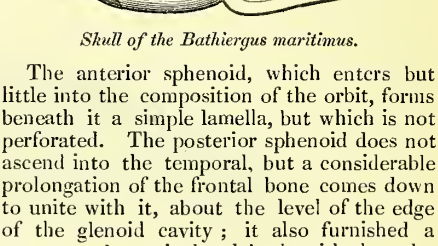
In the *beaver*, the frontals are consolidated together at a very early age ; the parietals also unite to each other and to the frontals, even before the inter-parietal has become blended with them. The inter-parietal is triangular, and in very young subjects is double. The glenoid cavity is broader than it is long; its external border only is formed by the jugal bone ; its posterior margin is altogether free. The tympanum is altogether formed by the tympanic bone. Between the two tympana the basilar region of the cranium is hollowed to such an extent as to be partly membranous, even in very old animals.

There are two mastoid tubercles placed near to each other ; one formed by the petrous bone, the other by the occipital. The petrous bone becomes united at an early period to the tympanic bone, a pointed apophysis of the temporal insinuating itself between them, behind the external auditory foramen.

The posterior sphenoid joins to the frontal in the temporal region ; the anterior sphenoid then mounts up very high ; and in adult specimens, when the molar teeth have come down, and the maxillary bones are no longer distended, there is inferiorly a compressed portion, by which the sphenoid joins the maxillary and the palatine bones, and which forms a partition pierced with several holes between the bottom of the two orbits.

In the *Cape mole* (*Bathiergus*) the sutures at the upper part of the cranium are disposed much in the same way as in the beaver, only in the larger species the temporals are broader anteriorly, and encroach upon the frontal in front of the parietal. The inter-parietal is of an oval shape. The temporal presents, posterior to its arch, a large fissure, which is not closed by the os petrosum : the latter bone, however, on the other hand, fills up a deep notch, which exists on the external border of the occipital bone. The paramastoid apophysis is dilated into a prominent plate.

Fig. 252.



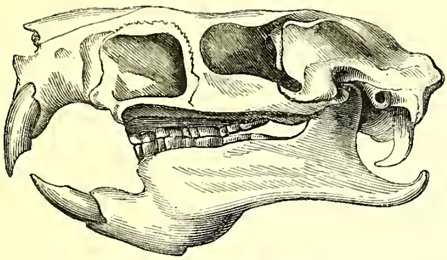
Skull of the Bathiergus maritimus.

The anterior sphenoid, which enters but little into the composition of the orbit, forms beneath it a simple lamella, but which is not perforated. The posterior sphenoid does not ascend into the temporal, but a considerable prolongation of the frontal bone comes down to unite with it, about the level of the edge of the glenoid cavity ; it also furnished a process to be articulated both with the palatine and the maxillary bones.

In the *ondatra* and the *water voles* the parietal bones are, as it were, imbedded in the shape of a disk between the temporals. The temporal, moreover, furnishes a prominent projection, that might be mistaken for the

post-orbital apophysis of the frontal, which latter does not exist. The frontal bones,

Fig. 253.



Skull of the Ondatra.

which are consolidated together long before the parietal, are much reduced in size, in consequence of the extension of the temporals, and the narrowness of the inter-orbital space.

The inter-parietal remains for a long time distinct, it is very large, and is situated between the two parietals, the two temporals, and the sphenoid.

The posterior sphenoid mounts much higher into the temporal region than in the genus Bathiergus, and joins both the temporal and the frontal. The parietal does not reach within a considerable distance of it. The tympanum is prominent, and rests posteriorly upon a well-marked paramastoid process. The suture between the tympanic and the petrous bone exists till a late period. The occipital portion of the petrous bone forms no tubercle, but penetrates deeply into the occipital.

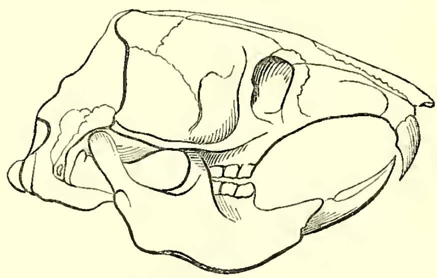
In the rats, properly so called, the frontals which remain separate for a long period, are distinguished from the parietal by the intervention of a straight transverse line. Their inter-parietal is rectangular and placed transversely, but does not reach as far as the temporal bones. The posterior sphenoid does not mount into the temporal region to a greater height than the anterior; it there joins the frontal, but remains separated by a considerable space from the parietal.

In the *gerbilles* the fronto-parietal suture forms the arc of a circle. The inter-parietal is broad transversely; its suture with the parietals is nearly straight, and it is embraced posteriorly and laterally by the occipital. The temporal, upon the sides of the cranium, is comparatively small in front; it touches the frontal at the extremity of the frontop-arietal suture; posteriorly it continues the suture, which, descending from the inter-parietal angle, separates the parietal from the occipital: the latter bone is deeply notched to receive the os petrosum, which it separates from the inter-parietal by a quadrilateral process. The arrangement of the bones in the orbit resembles that of the genus *Mus*. The tympana are extremely vesicular and prominent; they bound posteriorly the glenoid cavity, which resembles a deep furrow. There are small paramastoid apophyses closely applied to them.

In the *hamster* (*Cricetus*) the inter-parieta is a small tri angular bone; the temporal is extended at the expense of the parietal, and stretches as far back as the occipital. The orbital and temporal alæ of the sphenoid are arranged in the orbit as in the rats. There is no paramastoid process behind the condyles of the lower jaw.

The same observations are applicable to the *dormice*, but their inter-parietal bone is elongated transversely, so as to touch both the occipital, the parietal, and the temporal; the posterior sphenoid, moreover, only touches the maxillary by its apex. A little process, derived from the palatine, separates them below. These animals have the zygomatic arch situated lower down and broader than the hamsters. Their tympana are much larger, well rounded, and in contact with the internal pterygoid processes.

Fig. 254.



Skull of the Spalax typhlus.

In the *rat moles* (*Spalax*) the occipita bone is flanked by the ossa petrosa and the temporals, to form the occipital surface of the cranium; but the occipital suture is as usual situated in front of the occipital crest—a circumstance which encroaches much upon the parietal bones. This disposition is in relation with the strength of the muscles that support the head. The parietal encroach upon the frontal by a pointed process. The temporal ridges unite together to form a single sagittal crest, and the zygomatic arches are very prominent, externally corresponding to the great size of the temporal muscles. There is no inter-parietal bone. The tympana are but slightly arched.

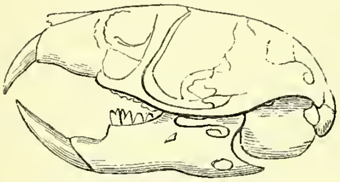
In the *rhyzomys* of Sumatra, on the contrary, it is the frontal which extends by a pointed process between the parietal; and, moreover, the temporal bones mount upwards very high upon the cranium, so as to join the frontal; there is no inter-parietal bone visible. The os petrosum is visible upon the occipital aspect of the cranium. A process derived from the temporal, which contributes to form the occipital ridge, is interposed between the os petrosum and the external auditory tube. The tympanum is lofty and well-rounded, and separated from the petrous bone behind by a process of the occipital, which terminates in a paramastoid tubercle.

In the *jerboas* (*Dipus*, Gmel.), the lines of separation between the frontal and parietal

bones form a perfect cross; the inter-parietal bone is large and of a rhomboidal shape.

In the alactaga (*Mus jaculus*, Lin.), a species of the same genus, the inter-parietal is

Fig. 255.



Skull of the Dipus hersipes.

separated from the temporal by a broad process divided from the occipital, which runs to join the parietal, as in the gerbilles (*Gerbillus*, Desmar, *Meriones*, Ilig). The os petrosum occupies a considerable space in the occipital region; but in the jerboa (*Dipus*) the great development of the ear renders important changes in the structure of this portion of the skull indispensable. All the hinder portion of the temporal bone is reduced to a thin osseous band, which is closely connected with the dilated tympanum and with the os petrosum, surrounding entirely the auditory canal. Another narrow band is derived from the summit of the occipital bone, which runs to become united at a right angle with the above process derived from the temporal, so that a small triangular space is formed between the parietal, the occipital, and the temporal, in which is visible, at the upper part of the skull, that great vesicular mass, which occupies a part of its base and its posterior aspect. The paramastoid apophysis is a little tubercle which leans against the tympanum, and bounds posteriorly the articulating surface of the lower jaw.

In the *helamys* (Cape jerboa, or jumping hare), the structure of the skull in the vicinity of the ear is analogous to that of *Dipus*. The petrous bones arise to the upper part of the cranium, and there occupy a considerable space between the temporal and the inter-parietal bones, so that the temporals only give off a narrow band posteriorly, which does not reach the occipital bone, and does not surround the auditory passage, as in the jerboa. From the absence of any slip derived from the occipital bone, the upper portion of the os petrosum is not divided into two parts, as it is in the jerboa. The tympanum also is much less developed, and in its vicinity there is a very distinct paramastoid process. The inter-parietal, which is triangular, moreover, touches the parietals, the ossa petrosa, and the occipital. The lines of separation between the frontals and the parietals form a cross; the former are much larger than the latter. The anterior sphenoid is perforated at the bottom of the orbit. The temporal alæ do not ascend higher than the orbital, and remain widely separated from the parietal.

In the *echimys* (or porcupine rat of Azzara), the line which separates the frontal from the parietal bones is straight. The inter-parietal is obliterated at an early age. A very distinctive character peculiar to the echimys is, that the occipital bone, as it descends laterally towards the ear, bifurcates in such a way as to enclose the ascending portions of the tympanic bone and of the os petrosum, forming by itself both the mastoid tubercles instead of the posterior one only, as is usually the case.

The anterior sphenoid gives off an orbital plate, which is moderately elongated; but the posterior is almost excluded, both from the temporal region and from the orbit, owing to the length of the temporal front of the suture in this part. It is hardly visible except at the base of the cranium. The articulating surface for the lower jaw is of a transverse form without any marginal boundary behind.

In the *capromys* the bifurcation of the occipital bone is equally distinct, but its two processes join inferiorly in such a way, that only a small hole is left occupied by the os petrosum. The orbital wing of the sphenoid is also less extensive.

In the *porcupines* the frontal bones are very wide in front between the lachrymals. In young animals, a large semi-oval inter-parietal is met with; but this bone, as well as the parietals and the frontals, unite at a very early period into one piece; they also at an early age become consolidated with the ossa nasi, so that these seven bones not only form one piece, but even become united to the temporals and to the occipital long before the bones of the face are anchylosed with each other. The os petrosum is scarcely discoverable at the back of the cranium, where it only forms a small tubercle embraced by two processes of the occipital, the interior of which represents the mastoid process of the temporal bone, and forms, external to the condyles of the lower jaw, a broad paramastoid apophysis. The posterior sphenoid does not reach so far as the orbit, or rise above the anterior, which latter is but slightly visible upon the exterior of the skull.

In the *coendou* the parietal bones are prolonged by a pointed process between the frontals; the suture between them, and also between the inter-parietal and occipital, is obliterated. The tympanum is much arched; the os petrosum hardly appears in the occipital region of the skull, but is slightly visible a little behind the tympanum above the paramastoid apophysis, which is of moderate size.

In the *paca* the frontal bones are much elongated; the suture between them and the parietals is transverse; the temporal extends backwards as far as the occipital ridge, and descends behind the tympanum over the base of the mastoid process, the point of which belongs to the occipital bone. The relations of the sphenoid orbital plates are as in the agouti, but the tympana are less prominent.

In the fœtus, and in very young subjects, there are two parietal and two inter-parietal bones; but these four pieces become at an early age consolidated into one.

In the *Guinea-pig* (*Cavia*) the parietal

bones and the inter-parietal, which is large, and of a semi-oval shape, are at an early period consolidated into one piece. The occipital bone extends beyond the occipital crest in the upper region of the skull, but the sides are formed by the temporal. The petrous bone, which is in early age consolidated with the tympanic, is slightly visible by a narrow slip in the occipital region.

The tympana are much arched, but the pterygoid processes do not touch them, because the *foramen lacerum anterius*, which is very large, separates them. The superior maxillary bone is articulated posteriorly with the posterior sphenoid above the palatine, upon the occipital region of the cranium.

In the *couia* (*Myopotamus*, Commerson) the sutures between the frontal and parietal bones form a complete cross. The inter-parietal is united to the surrounding bones at an early age, but in young individuals it is very large, and divided into two pieces; in the adult animal the zygomatic processes of the temporal bone formed at their extremities a strong hooked process, which winds down beneath the jugal bone. The posterior sphenoid does not enter into the composition of the orbit; the os petrosum is visible externally in the occipital region of the skull, situated between the two mastoid processes, which are both formed by the occipital bone, but are of very unequal length; the external is pointed, the inferior and internal is of much greater size, running backwards and outwards, compressed, pointed, and recurved.

In the *agouti*, the frontal and nasal bones remain separate, although the parietal and inter-parietal are united into one piece; in young subjects the inter-parietal is of great size, and semicircular in its shape. The orbital plate of the sphenoid enters largely into the composition of the orbit, where it articulates by it posteriorly with the temporal. In the preceding genera it is to be remarked, that the posterior sphenoid is joined to the frontal, which is interposed between the temporal and the orbital alæ of the sphenoid; the tympana regularly arched. The os petrosum does not appear externally, but in addition there here re-appears a small portion of the ethmoid, interposed between the orbital ala of the sphenoid, the frontal and the lachrymal bones.

In the *capybara* the hinder portion of the cranium, as well as the occipital bone and the inferior region of the temple, resemble what is met with in the kerodon of Patagonia. The paramastoid apophysis is excessively long, the tympana are small. The petrous bone does not appear at all in the occipital region of the cranium. The parietals and inter-parietals are consolidated into one piece at a very early age, and separate, by a process more acute than in any of the preceding genera, the cranial portion of the temporal bone into two branches; the frontals are likewise united together in very young animals.

In the *viscache* the squamous portion of the temporal bone is likewise deeply indented by a point derived from the parietal. The posterior branch of this bifurcation, which is narrow at its commencement, enlarges as it approaches the occipital ridge. The inter-parietal and the parietals are united into one piece, the frontals are distinct, and the coronal suture is transverse. The zygomatic process of the temporal is directed almost horizontally, and this bone remains widely separate from the maxillary; the posterior sphenoid unites with this latter bone, external to the palatine, which does not penetrate into the temple or into the orbit: the posterior sphenoid has no temporal ala, so that it reaches neither the frontal nor the parietal bone—a circumstance which has been already remarked in preceding genera.

In the *kerodons*, the frontal bones remain separate after the parietal and inter-parietal are conjoined. The fronto-parietal suture is transverse. The superior margin of the occipital is bent upon itself at a right angle, as in the hares, and articulates at the side of the cranium with the temporals, terminating laterally by a long, slender, vertical, paramastoid process. The temporal gives off posteriorly a lamina, or apophysis, which descends more or less in different species between the tympanum and the petrous bone. The latter bone is not visible externally in the occipital region, but is apparent upon the side of the head, above and behind the auditory passage. The connections of the bones in the orbit are not less remarkable than in the Guinea-pig. The temporal is in like manner developed at the expense of the posterior sphenoid; but it is the former which becomes united by its apex to the extremity of the maxillary bone, the sphenoid which runs parallel with it only approaching the maxillary, from which it is separated by a slip derived from the *os palati*. The temporal, as in the preceding genera, is united in the orbit to the anterior wing of the sphenoid in the Guinea-pig, with this difference, however, that the temporal leaves it free externally. The petrous bone occupies a considerable surface in the occipital region of the skull, and likewise furnishes a mastoid tubercle at the base of the paramastoid apophysis, which resembles that of the couia; and which, at first, running outwards and backwards, suddenly bends inwards and forwards. The petrous bone occupies a large part of the occipital region, where it presents a flattened surface; it also furnishes a mastoid tubercle at the base of the paramastoid apophysis, which resembles that of the couia, and which, at first, directed outwards and backwards, afterwards suddenly bends inwards and forwards.

In the *chinchilla* the connection of the frontal and of the parietal bones, as well as those of the sphenoid with the maxillary and with the temporal, are the same as in the viscache, but the great development of the ear causes differences in the posterior region. The paramastoid apophysis, which is strongly marked, is closely applied against the tympanum, and does not project inferiorly. The petrous bone, instead of presenting a flat sur-

face in the occipital region of the skull, is extremely dilated, insomuch, indeed, that this dilatation appears in the upper wall of the skull, in the shape of two large projections, bounded in front by the parietals, internally by a plate common to them and the occipital bone, and posteriorly by a long narrow transverse projection from the occipital, which is in contact with the petrous bone, and externally by another thin and pointed slip, which forms the posterior termination of the temporal bone, and which projects above the auditory meatus to join that derived from the occipital. We have seen, above, that in the jerboa a similar disposition exists.

Bones of the face.— In the Rodentia the intermaxillary bones are of enormous dimensions, on account of the great size of the incisor teeth, so that the maxillary bones are pushed very far backwards; these latter form a large portion of the inner wall of the orbit, into the composition of which the os palati enters but slightly, and sometimes, indeed, not at all. The anterior boundary of the orbit is formed by a process of the maxillary bone, which proceeds to contribute to the formation of the zygomatic arch in such a way that the os malæ is, as it were, suspended in the centre of the arch between the apophysis, derived from the maxillary and the zygomatic process of the temporal bone.* It joins neither the frontal nor the sphenoid. The elongation of the ossa nasi is such that the opening of the nose is situated quite at the extremity of the snout.

In the *aye-aye* the bones of the nose are short and broad. The intermaxillaries mount up along their sides by a broad process, which occupies part of the snout, and are articulated to the frontal by a tolerably broad space; they touch, likewise, the lachrymals which encroach upon the cheek; while the canal situated between the latter bones, the maxillary, and the jugal, is out of the orbit. The jugal apophysis of the maxillary arises opposite the second molar tooth, and the boundary of the jugal bone is placed at the anterior base of the zygomatic arch. It articulates with the lachrymal, both within and without. The orbit is very broad, and furnishes a large post-orbital apophysis, which joins that derived from the frontal bone. The palatine bone advances but a little way into the palate, terminating by a straight suture between the last molar teeth. The palatine portion of the pterygoid alæ is simple; their sphenoidal portion is divided into two laminæ, the external of which is prolonged as far as the tympanum, to which it is articulated, as well as to the inner border of the glenoid surface. In the temporal region, the palatine bone remains behind the posterior margin of the maxillary, between the latter bone and the two sphenoids, only touching the frontal by its apex.

In the *hares*, the intermaxillary bone presents, besides its palatine portion, which is large, a long ascending apophysis, which is at first imbedded between the maxillary and the os nasi, and subsequently between the latter and the apophysis of the frontal, to which latter it is connected. All that portion of the maxillary bone which forms the cheek is, in the adult animal, riddled with holes, so as to have the appearance of lace-work. The lachrymal in the orbit is tolerably large; externally, it gives off a blunt hook, beneath which is the lachrymal canal, situated upon the very edge of the orbit. The zygomatic portion of the maxillary bone is short; its inferior margin forms a ridge, which projects slightly externally, and presents a flattened surface, from which arises one of the portions of the masseter muscles. It is this surface which we shall see in other Rodentia become rounded into a more or less oblique vaulted space, and in others become transformed into a wide ring. The union between the maxillary and the jugal bones is so soon obliterated, that unless we examine very young individuals we should be tempted to believe that no jugal existed. This latter bone is arched inferiorly, and extends by means of a process beneath the zygomatic portion of the temporal bone. Besides the floor with which it covers the roots of the teeth, the maxillary gives off a narrow plate, which mounts into the orbit as high as the os frontis, between the lachrymal, from which, however, it is separated by a membranous space and the anterior sphenoid. The vomer is visible at the hinder part of the septum, which separates the foramina incisiva. The palatine occupies beneath the anterior sphenoid in the orbit a much greater space than in other Rodents; inferiorly it extends as far as the third molar tooth, and is deeply indented as far as the fourth. The pterygoid alæ extend to the azygos portion, or to the body of the anterior sphenoid, but they are separated from that of the posterior sphenoid by a membranous space on each side. The posterior sphenoid has on each side two pterygoid plates, which are both of them contiguous to those of the palate bones; the internal ones terminate in a slender point or style.

In the *lagomys*, the base of the zygomatic arch gives off a process, which is directed downwards; and the jugal bone, after having passed beyond the zygomatic process of the temporal, is prolonged directly backwards into a lengthened point.

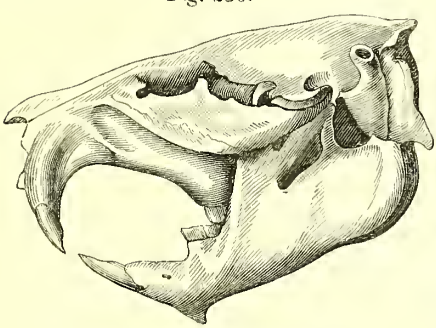
In the *marmot*, the two nasal bones constitute the middle of the upper vault of the snout. On each side of them the ascending apophysis of the intermaxillary bones, which are broader than in the hares, run up to be articulated with the frontal, the anterior border of which is transverse and only slightly festooned. The external surface of the maxillary is concave beneath a ridge, which is continuous with that of the zygomatic arch, extending as far as the intermaxillary suture. Setting off from this point, the intermaxillary suture descends vertically to embrace the

* It will be seen from the details that follow, that the part played by the os malæ in the construction of the cheek is not always so simple.

palate, of which it occupies rather less than a third. The jugal bone reaches to the anterior base of the zygomatic arch, where it articulates with the lachrymal as well as with the maxillary bonc ; it is connected with the zygomatic apophysis of the os temporis by a horizontal suture, which occupies all the second half of the arch, so that it extends as far back as the glenoid cavity, the external margin of which it fills. The laehrymal is of moderate extent in the orbit, but is scarcely visible beyond the margin of that cavity; besides its canal, whieh is altogether within the orbit, there is a small unossified space between it and the maxillary bone, situated very near to the posterior opening of the sub-orbital canal. The large spaee oecupied by the maxillary in the orbit keeps the lachrymal widely separated from the palatine bone, with which it articulates so extensively in the Carnivora. The palatine bone occupies, posteriorly, about one-fifth of the extent of the palate. After having formed the root of the pterygoid alæ, it is prolonged between them for about half their length laterally ; it mounts up into the temporal region as high as just beneath the optic foramen ; it there spreads out backwards as far as the spheno-orbital foramen, and forwards, as the foramen which represents the spheno-palatine. The internal pterygoid process is not detached from the sphenoid, and terminates posteriorly in a long hook. The external pterygoid plate is very distinct; although but little prominent, it covers the vidian foramen, and touches with its point the extremity of thc maxillary.

In the *squirrel*, the lachrymal hook is formed by the bone of that name ; but it is also doubled by a similar unciform process, derived from the jugal. There is no mcmbranous space between the lachrymal and the maxillary. The prolongations of the palatine bone between the pterygoid alæ are shorter. In other respects the relations of the bones to each other are very similar to what exists in the marmot.

Fig. 256.



Skull of the Beaver (*Castor Fiber*).

In the *beaver*, the post-orbital apophysis of the os malæ is very large and blunt, and all this portion of the bone very broad ; it occupies the greater portion of the zygomatic arch. The two nasal bones are broader in their middle, and both the intermaxillary and maxillary bones reach up as far as the frontals. The lachrymals are small, especially that portion of them which is situated without the orbit, to which the jugal bones touch. The vaulted portion of thc maxillary bone is very extensive and well circumscribed in adult animals; on its external margin, by the ridge, which is con'inuous with the inferior edge of the zygomatic arch, and internally by another ridge, which commences close to the suborbital foramen, and mounts up on the cheek to join the ridge last mentioned. The palatine bone occupies in the palate a triangular space, extending as far forward as opposite the second molar tooth; it terminates posteriorly between the two pterygoid alæ. The external pterygoid apophysis is of moderate length, nearly rectangular in its shape, and is pierced at its base by the vidian canal : it articulates broadly with the posterior part of the maxillary in such a way as to exclude the palatine both from the orbit and from the temple. The internal pterygoid apophysis is of a hooked form, the point of the hook reaching as far as the tympanum.

In the *oryeteres*, the jugal bone commences at about the anterior fourth of the length of the zygomatic arch, and consequently remains widely separated from the lachrymal. The ossa nasi constitute scarcely half the breadth of the snout, in which the maxillary occupies much less space, it being here the inter-maxillary which principally forms it. The last-mentioned bones mount up upon the forehead higher than the bones of the nose—a circumstance which is the reverse of what occurs in the beaver. The concavity of the maxillary beneath the base of the zygomatic arch is reduced to a slight oval depression; but its zygomatic apophysis is very long; it is the maxillary bone and the frontal, to which it is joined by a long suture, which forms almost alonc the osseous walls of the orbit. There is no lachrymal suture visible, although the lachrymal canal is distinct enough. The external pterygoid apophysis presents neither crest nor prominent angle ; the internal resembles that of the beaver.

In the *ondatra* and the *water voles*, the bones of the nose, which are pointed at their summits, are considerably enlarged at their inferior extremities. The intermaxillaries occupy a smaller portion of the snout than the preceding pieces, the oblique excavation at the root of the zygomatic arch exists; but it is separated from the cheek superiorly by the vertical prolongation of the sub-orbital foramen. The malar apophysis of the maxillary extends beneath the jugal until it almost reaches that of the temporal; so that the jugal is only free at its lower margin for a very small space, and is very far removed from the lachrymal, which latter bone does not appear external to the orbit, it being concealed in the sub-orbital canal. The os palati extends into the palate as far as the first molar tooth, but is not visible either in the orbit or in the temple, in which latter region the maxillary is connected to the two sphenoids and to the

frontal, as far as the lachrymal. The two pterygoid alæ are well developed and of equal size; the internal are connected with the tympanic bones, as are the external; and by their anterior margins the latter are connected with the maxillary to a greater extent than in the beaver, so that no part of the palatine is visible externally.

In the *rats,* properly so called, the bones of the nose likewise increase in breadth, towards their extremity, to an extent which varies in different species. The intermaxillaries are joined to the frontal by a suture consisting of extremely fine and numerous indentations: they form scarcely the half of the snout, comprehending the vault and the roof of the zygomatic arch, which is here directed much further outwards, and is separated from the rest of the cheek by a deep groove; in front of this groove the maxillary is excavated into a sort of pouch, its zygomatic process is very long, the jugal bone short and slender. The lachrymal is entirely contained within the orbit, no part of it being visible at the point of union between the frontal and maxillary upon the margin of the orbit, but a prominent hook-process, situated within the edge of the orbital cavity. The palatine fills up half the space situated between the foramina incisiva and the hinder margin of the palate; its pterygoid wings, moreover, are considerably prolonged between those of the sphenoid, but the external pterygoid alæ of the latter bone entirely cover it externally by passing to join the maxillary, as in the ondatra, nevertheless it shows itself in the floor of the orbit embraced in a fissure of the maxillary bone. The points of the internal pterygoid apophyses do not reach as far as the tympanum. There is between the pterygoid alæ a membranous space.

In the *gerbilles,* the bones of the nose and the intermaxillaries are prolonged in front, a little beyond the incisor teeth; the suture between the intermaxillary is composed of radiated indentations; the maxillary bone expands into a very thin lamina at the anterior margin of the orbit; and this lamina is continuous with another given off at this point by the lachrymal; the jugal bone is very slender; the palatine runs forward in the palate as far as the middle of the first molar tooth; posteriorly it is not visible in the orbit, the articulation of the external wing of the sphenoid with the maxillary concealing it on the outer side, as in the preceding genera. The internal pterygoid apophysis reaches as far as the tympanum.

In the *hamsters,* the bones of the face closely resemble in their disposition those of the rats properly so called. In the *dormice* (*Myoxus*), as in the gerbilles, the end of the snout projects beyond the incisor teeth; and the intermaxillary bone occupies a large portion of the snout; whence it results that it is prolonged upwards by a short ascending branch. In *Myoxus nitela* the maxillary presents beneath the sub-orbital hole a prominent tubercle, which does not exist in the dormouse (*Myoxus Glis*). Both of them have a membranous space in each of their palatine bones; and, moreover, this bone retakes its usual position between the maxillary and the sphenoid upon the outer side of the pterygoid ala, so that the latter is only in contact with the maxillary by its apex, nearly in the same manner as in orycterus.

In *spalax* (the rat mole), the bones of the nose become at an early period consolidated together for a portion of their length, they expand inferiorly, and are proportionally of larger size than in orycteres. The process of the maxillary which surrounds the infra-orbital hole is broad and thin; the jugal is very slender, and does not at all contribute to form the inferior rim of the orbit; the external pterygoid apophysis almost covers the foramen ovale.

In the *rhizomys* of Sumatra, the fronto-maxillary suture continues the line of union between the frontal bone and the other bones of the face. The bones of the nose are separate, and the frontals consolidated together: the bones of the nose are here of a triangular form. The lachrymal is entirely contained in the orbit; the jugal, which is broad, occupies the centre of the zygomatic arch; the palatine is small, and of a triangular shape in the region of the palate; it is not visible in the orbit, on account of the union between the ala of the sphenoid and the maxillary bone, which is as extensive as in the ondatra. The internal pterygoid apophysis is prolonged into a long hook.

In the *jerboa,* properly so called, and in the *alactaga,* the jugal ascends at a right angle along the posterior edge of the great pre-orbital ring as far as the lachrymal, with which it is connected. In the jerboa this part is enlarged into a broad lamina; in the alactaga it is a simple, stem-like process. The maxillary takes beneath the sub-orbital hole the form of a large ring, which might almost be mistaken for an orbit. The lachrymal forms towards the upper part of this ring a broad hood-like process. The bones of the nose cover the whole upper part of the snout, and are even bent a little into a tubular form at their extremity. The ascending ramus of the intermaxillary is very narrow at its origin, between the nasal and the maxillary; it afterwards spreads out as it approaches the frontal, with which it is connected on a level with the bones of the nose by a finely serrated suture.

In the *pœphagomys* the jugal is broad, it gives off a post-orbital apophysis, and does not mount along the pre-orbital ring. The face of this animal offers a very remarkable peculiarity. A cylindrical tube, bent into an arched shape, traverses the great ring, and is applied beneath the orbit against the alveolar arch. In this genus, as in the preceding, the maxillary is connected with the sphenoid.

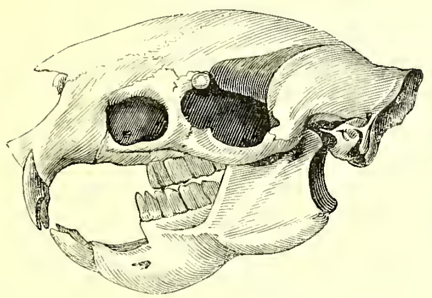
In the *helamys* the jugal is broader, and extends along a little more than half of the ring; the rest is completed by the lachrymal, and even by the frontal bone. The lachrymal in this genus has no hook-like process: after having shown itself external to the orbital

ring, it occupies a considerable space in the orbital cavity; but the entrance of the lachrymal canal is concealed by the sub-orbital arch. The bones of the nose are singularly robust; the ascending ramus of the intermaxillary is, on the contrary, very narrow, even at the point where it joins the frontal. The pre-orbital ring is of large size, and the malar apophysis of the maxillary arises close to the intermaxillary suture. A few lines behind the incisor teeth the palatine interposes itself, under the shape of a round shield-like plate, between the sphenoid and the maxillary.

In the *echimys* the jugal is very long, and tolerably broad; the lachrymal is small, and is furnished with a little hook-like process; the maxillary presents, inferiorly, in front of the molar teeth, a small fossa and a malar apophysis, the margin of which is broad and flattened. The bony arch of the pre-orbital ring is simple, and not doubled posteriorly by an ascending apophysis of the jugal, as is the case in the jerboa; or by the latter and the lachrymal, as in the helamys and the viscache. The palatine is deeply indented posteriorly, but it ascends into the orbit, and likewise appears in the pterygoid ala, between the sphenoid and the maxillary. The external pterygoid alæ do not extend transversely beneath the foramen ovale.

The *capromys* very nearly resembles the preceding genus in the construction of its face, but in it the jugal bone is broader, and almost rhomboidal in its shape. The sphenoid also is in contact with the maxillary, above the point of union between this bone and the pterygoid portion of the palatine.

Fig. 257.



Skull of the Porcupine (Hystrix cristata).

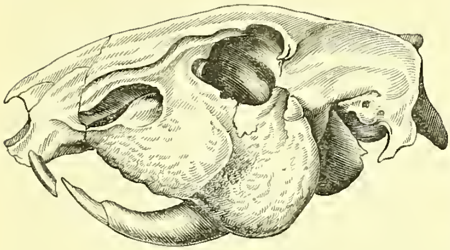
In the common *porcupine* (*Hystrix cristata*, Lin.), the bones of the nose are very large and broad, the suture connecting them with the frontal mounts much higher up than the intermaxillary sutures. The intermaxillary bones have their ascending ramus much less narrow than in the preceding genera. The maxillary is hence a pre-orbital ring, which is much broader than it is high; and the inferior horizontal portion of its circumference is much more slender than the vertical posterior portion. The lachrymals consist of a small portion situated external to the orbit, which furnishes a little hook-like process, and of another portion situated within the orbit, which is also of small size. The jugal is of moderate dimensions, and broader in front than it is posteriorly; the palatine is deeply indented, and only sends off a little tongue-like pointed process to penetrate the orbit; but it completely separates the sphenoid from the maxillary. The internal pterygoid processes end in hook-like terminations, the extremities of which are united to the tympanum; the external ones only represent a transverse bar, into the composition of which the palatine slightly enters.

In the *cuendu* (*Hystrix prehensilis*, Lin.), the bones of the nose are short and flattened at their anterior portion; they are likewise remarkably broad and mount very high up. The pre-orbital ring is higher than it is broad. The internal pterygoid process extends as far as the tympanum. In the *ursons* (*Hystrix dorsata*, Lin.), the pre-orbital ring is larger than in either of the preceding genera, and its two arches are of equal strength; the bones of the nose are short, flat, and one third narrower than those of the cuendu. In both genera, the lachrymal is united, at an early age, both with the maxillary and the frontal. The intermaxillary suture is straight and almost vertical In the *coui* (*Myopotamus*, Commerson; *Mus coipus*, Molin.), the bones of the nose are broad and much elongated; they do not mount higher than the intermaxillaries. The suture between the latter bones forms a very rounded arch, which is concaved posteriorly. The maxillary has the inferior edge of its malar apophysis very much flattened. The pre-orbital ring is large. The palatine is in contact with the maxillary below, but above the sphenoid joins that bone likewise, as in Orycterus and other genera.

In the *agouti* (*Chloromys*, Fred. Cuv.; *Dasyprocta*, Ilig.), the lachrymal, which is larger than in the allied genera, contributes to surround the sub-orbital foramen superiorly, so that the ring formed around this hole by the maxillary is not complete. The lachrymal comes down very nearly as far as the jugal bone, but does not touch it. The jugal itself is very small. The pre-orbital ring is broader than it is high; and there is, moreover, internal to it, situated upon the cheek just above the commencement of the malar apophysis, a long oval sinus, into which, both before and behind, a rounded canal opens. Inferiorly, the palate bone advances in a wedge-like manner as far as opposite to the first molar tooth; it penetrates into the orbit by a thin slip, which separates the sphenoid from the maxillary. The internal pterygoid alæ are prolonged as far as the tympanum by a broad hook-like process; the external form simple plates, to the construction of which the palatines partially contribute. There is a membranous space on each side, at the base of the union between the palatines and the internal pterygoid. In the *pacas* (*Cœlogenys*, Fred. Cuv.; *Cavia Paca*, Lin.), the maxillary portion of the zygomatic arch conceals beneath it an enormous sinus, which is less deep in very young subjects than in adult animals. This swelling, which fills up a portion of the

pre-orbital ring, causes the latter to be much elongated transversely. And towards its in-

Fig. 258.



Skull of the Cœlogynus.

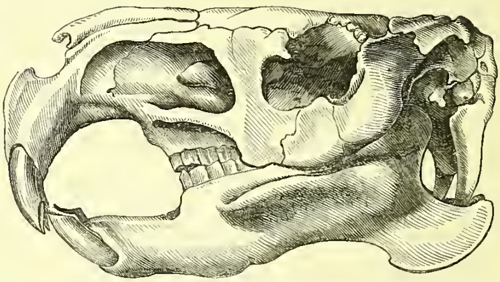
ner angle there is an excavation resembling a long furrow or semi canal, which is really the infra-orbital canal. The jugal is much higher than it is broad; the palatine extends into the palate as far forward as the first molar tooth: in the orbit it is almost hidden by the projection of the maxillary; nevertheless, it is interposed between that bone and the sphenoid, and at the posterior extremity of the alveolar arch.

In the *Guinea-pigs* (*Anœma*, Fred. Cuv.; *Cavia*, Ilig.; *Mus porcellus*, Lin.), the lachrymal is large; but it does not entirely form the upper root of the pre-orbital ring, and the maxillary is not interrupted at this point. The pre-orbital ring is much wider than it is high. We may remark in this genus both the groove of the paca and the fossa of the agouti; but the latter is situated higher up, as in the rats. The ascending branch of the maxillary is long and narrow. The bones of the nose are broader in front than behind. The jugal only commences towards the middle of the zygomatic arch; the palatine, which superiorly does not penetrate either into the orbit or into the temporal region, extends in the palate only as far forward as the interval between the second and the third molar teeth.

In the *kerodons*, a small point of the frontal insinuates itself above, between the bones of the nose and the intermaxillaries, the ascending branch of the latter being very long, and extremely narrow at its origin, in the Brazilian species. In this species, likewise, the pre-orbital ring is oval, and much elongated transversely, but formed entirely in the maxillary bone as it is in the Guinea-pig; whilst in the kerodon of Patagonia the lachrymal forms by itself nearly the whole vertical portion of its arch, so that the lachrymal is necessarily of very great size. Posteriorly, the maxillary touches by its apex a long point derived from the temporal external to the palatine; the latter, however, is enclosed between the sphenoid and the maxillary, and mounts up into the floor of the orbit, when it is connected with the lachrymal bone. In the palate it is very deeply notched.

In the *capybara* (*Hydrochœrus*, Erxleben), the jugal is still shorter than in the Guinea-pig. The lachrymal is largely developed at the root of the vertical arch of the pre-orbital ring, but does not assist in forming it. The bones of the nose are very large and rectangular. The ascending ramus of the intermaxillary, on the contrary, is extremely narrow, and is only united by its point to a point derived from the frontal. The inferior horizontal arch of the ring is broad and flattened, with a little fossa at its base, as in the kerodons; the maxillary is connected behind with the temporal, near the glenoid facet, external to the palate bone; but what distinguishes capybara from them is, that this articulation is much more extensive, and that we cannot see, within, the long pterygoid apophysis and that portion of the palatine alluded to above. The external pterygoid alæ are obliterated; the internal alæ terminate by a rounded plate, which is very far from reaching as far as the

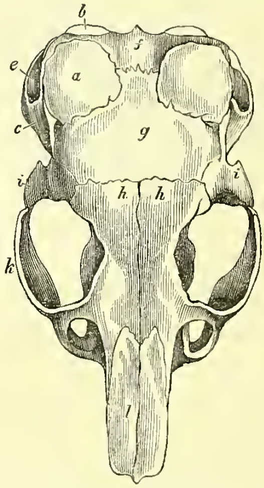
Fig. 259.



Skull of the Capybara.

tympanum. The palatine encroaches upon the palate as far forward as the third molar

Fig. 260.



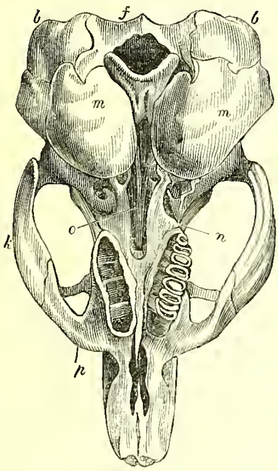
Skull of the Chinchilla.

a, *b*, *c*, portions of the temporal bone, which is here very remarkable on account of the extraordinary development of the tympanic cavity; *e*, meatus auditorius externus; *f*, the occipital bone; *g*, the parietal; *h*, *h*, the frontal; *i*, zygomatic portion of the temporal, which in this animal is quite detached from the preceding portions; *k*, malar bone; *l*, ossa nasi.

tooth, and is interposed behind, between the maxillary and the sphenoid.

In the *viscache* and the *chinchilla*, the bones of the nose are oval and elongated; the ascending branches of the intermaxillaries very narrow at their origin; but they enlarge as they approach the frontal, as in the jerboas. The maxillary, in both, forms the entire pre-orbital ring; but in the viscache the vertical portion of the arch is doubled posteriorly, as in the helamys, by an ascending branch of the jugal, by the lachrymal, and by the frontal bones. At the bottom of the ring there is a deep groove, almost entirely separated from it by a vertical plate, as in the alactaga. In the chinchilla, the jugal does not reach as far as the lachrymal, and in the pre-orbital ring there is only a very superficial furrow, with no vertical plate of separation. In both species the

Fig. 261.



Base of the skull of the Chinchilla.

b, *b*, tympanic portion of temporal bone; *f*, occipital bone; *m*, mastoid bone; *n*, palate bone; *o*, the sphenoid; *p*, the superior maxillary bone.

palatine is very deeply notched, it articulates with the maxillary, except externally, where a point of the posterior sphenoid touches the latter bone: moreover, on account of the entire absence of the external wall of the pterygoid fossa, the palatine is found to occupy a considerable space in the floor of the orbit, between the orbital alæ and the maxillary: it does not, however, mount upwards, as in the kerodon, between the latter bone and the frontal, to become connected with the lachrymal. The internal pterygoid apophysis is largely connected with the tympanum.

Bones of the carpus.— Generally, in the Rodentia, the os magnum is divided into two, as it is in the monkeys; in the *porcupine* this is not the case, but there is a supernumerary bone interposed between the os pisiforme and the metacarpal bone of the fifth finger connected with the os unciforme.

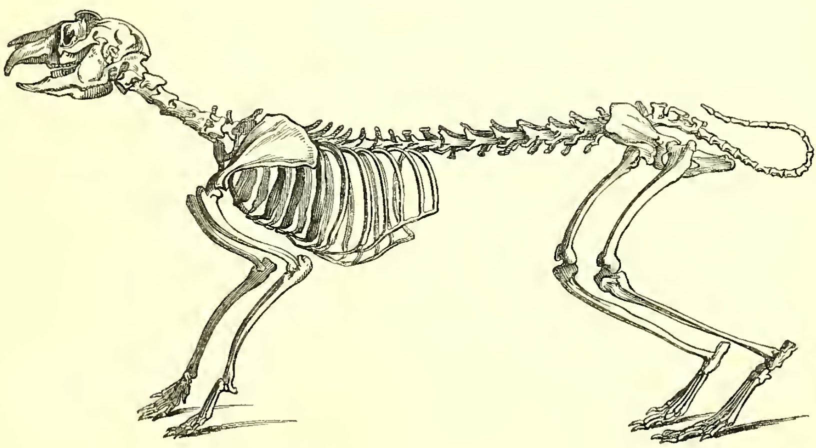
The *hare* and some other Rodents have one carpal bone more than the human subject; it is situated between the scaphoid, the trapezium, and the os magnum, of which last it appears to be a dismemberment; but the beaver, the marmot, the squirrel, the rats, and the agoutis have, like the Carnivora, a single bone representing the scaphoid.

The supernumerary bone is as large as the ordinary pisiform, and often much larger. Sometimes, as in the *jerboa* and the *marmot*, there are two supernumerary bones, so that, on each side of the wrist, there is a bone of equal size out of rank.

In the *capybara* the scaphoid and the semilunar bone are united without any supernumerary ossicle; a small one, however, exists in the Guinea-pig. The *paca*, the *agouti*, and the *capybara* have the os magnum divided; these three animals possess, as the rudiment of the thumb, a small bone situated upon the trapezoid, with which it is articulated.

In the *marmot* and the *agouti* this rudiment is composed of three ossicles; and there is, moreover, an internal supernumerary bone.

Fig. 262.

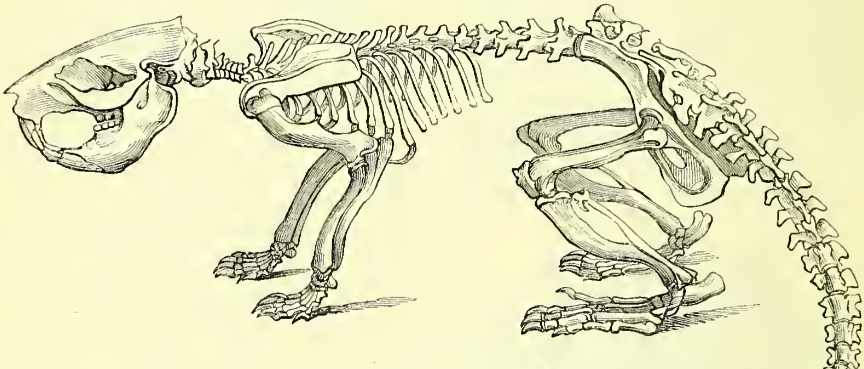


Skeleton of the Hare (*Lepus timidus*).

In the order Rodentia the structure of the *thumb* differs in different genera; there is a complete but short thumb in hares, beavers, and jerboas; an incomplete thumb, consisting of only two phalanges, in squirrels, rats, porcupines, pacas, and agoutis; and a thumb, represented by only a single ossicle, in the capybara, the Guinea-pig, the marmot, &c.

In connection with the *fore-arm* it may be observed, that the rabbit has only one pronator of the wrist, corresponding to the pronator teres; a circumstance easily accounted for by the very small degree of motion permitted between the bones of the fore-arm; in most other Rodentia, however, both the pronators are present.

Fig. 263.



Skeleton of the Beaver (*Castor Fiber*).

The *terminal phalanges* of the fingers are generally very slender, elongated, almost straight, and pointed, except in the capybara, which has its last phalanges of a triangular shape, and enclosed in strong horny hoofs.

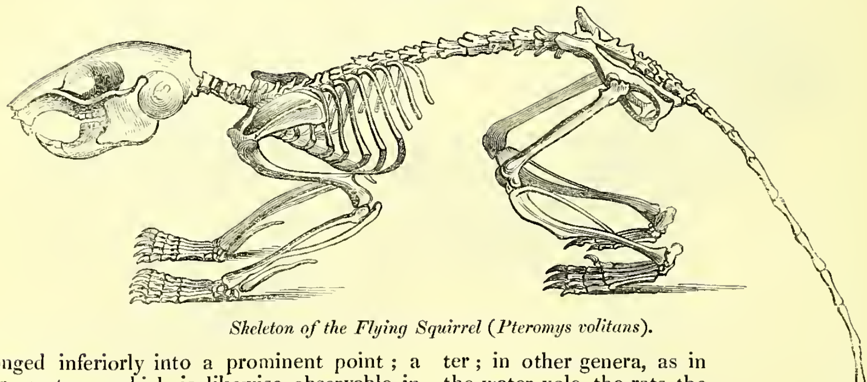
In those Rodentia which have a complete *clavicle*, the muscles of the shoulder resemble very nearly in their disposition those of the human subject. The *humerus* resembles that of the Carnivora in its mode of articulation with the fore-arm; but in those genera that are without clavicles, the articulation of the elbow joint resembles more nearly what is met with in herbivorous quadrupeds, being a simple hinge joint. The humerus of the beaver is much expanded at its ulnar extremity, and the deltoid crest is prolonged inferiorly into a prominent point; a circumstance which is likewise observable in the rat, the water vole, the ondatra, and in many other genera.

In the hares, the porcupine, the paca, and the agouti, the humerus near the elbow joint is completely perforated.

In the Rodentia the general form and position of the *pelvis* is nearly similar to what exists in the Carnivora.

The *femur* is in the beaver very broad, flattened from before to behind, and exhibits along its outer surface a sharp crest, which represents the linea aspera, and which is prolonged towards its middle into an apophysis, which has been named the third trochanter. This third trochanter is also met with in other rodents, as, for example, in the musk rat; in the hares it is placed so high up, that it appears to be a derivation from the great trochanter; in other genera, as in the water vole, the rats, the squirrels, and the marmots, it is a simple crest, or external linea aspera; in all the Rodentia the great trochanter is very prominent, and the neck of

Fig. 264.

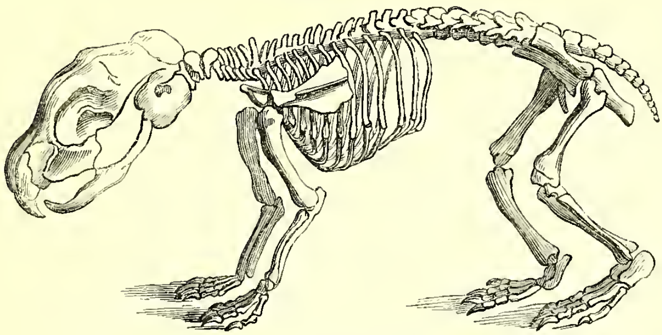


Skeleton of the Flying Squirrel (*Pteromys volitans*).

the thigh bone considerably narrower than its head.

its posterior aspect there is likewise a prominent crest. It results from this structure,

Fig. 265.



Skeleton of the Paca (Cœlogenys Paca).

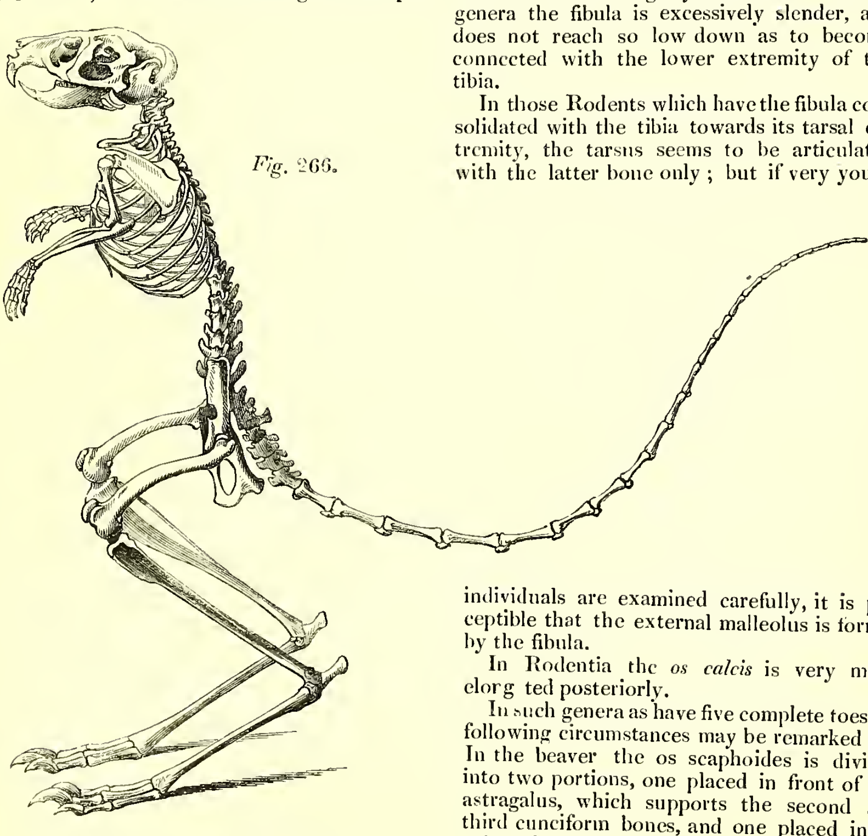
that, viewed from behind, the tibia exhibits, in the upper half of its length, two deep fossæ for the attachment of the tibialis posticus and the flexor longus pollicis. This structure is more particularly remarkable in the *ondatra*.

The Rodentia have the *fibula* situated quite behind the *tibia;* in rats, voles, jerboas, the beaver, the helamys, and the rabbit, it becomes consolidated with the tibia towards the lower third of its length, a wide triangular space being left between the two bones at the upper part of the leg; the anterior crista of the tibia in all the above genera is remarkably prominent, as is the internal edge; and upon

In the beaver the fibula gives off from its upper extremity a strong recurrent apophysis, which is directed slightly outwards. In some genera the fibula is excessively slender, and does not reach so low down as to become connected with the lower extremity of the tibia.

In those Rodents which have the fibula consolidated with the tibia towards its tarsal extremity, the tarsus seems to be articulated with the latter bone only; but if very young individuals are examined carefully, it is perceptible that the external malleolus is formed by the fibula.

Fig. 266.



Skeleton of the Jerboa (Dipus hersipes).
(Altered from Pander and D'Alton.)

In Rodentia the *os calcis* is very much elongated posteriorly.

In such genera as have five complete toes the following circumstances may be remarked: — In the beaver the os scaphoides is divided into two portions, one placed in front of the astragalus, which supports the second and third cuneiform bones, and one placed internal to the astragalus, to which is attached the cuneiform bone that supports the great toe,

and a supernumerary flattened bone situated along the inner margin of the tarsus. The same disposition of these bones exists in the genera spalax and capromys, in the marmot, squirrels, and porcupines; but in the four latter genera the supernumerary bone is of smaller size.

The rats and the paca have their os scaphoides divided, but are without any supernumerary bone. Among those genera which have only four toes, such as the helamys, or Cape jerboa, which has its foot exceedingly elongated, the inferior tubercle of the scaphoid, which is observable in the sole of the foot of all rodents, is very long and prominent. Upon the internal margin of the tarsus there are in this animal some elongated flat bones, which are the rudiments of the great toe.

In the jerboas, properly so called, both the internal and external metatarsal bones are extremely small, and the three others are consolidated into one bone, upon the distal extremity of which are three articulating surfaces which support the phalanges of the toes.

In the rabbit and the hare, animals which resemble the jerboa in the great size of the tubercle of the scaphoid, the rudiments of the great toe become consolidated at an early age with the metatarsal bone of the second toe.

In the capybara, the Guinea-pig, the mara, and agouti, which have only three toes, the internal portion of the scaphoid supports a single bone, representing the cuneiform and a rudiment of the inner toe; the cuboid likewise supports a small bone, which is a rudiment of the outer toe. The disposition of the toes varies considerably in the different genera of Rodents; in the beaver, the inner toe is nearly of equal length with the others; in the marmot, the porcupine, and the rats, it is considerably shorter; in the paca it is nearly obliterated; and in the Cape jerboa it is a mere rudiment, consisting of but a single bone; in the hares not even this rudiment is perceptible.

In the capybara, the agouti, and the Guinea-pig both the inner and outer toes are reduced to a single bone.

The jerboa (*Mus jaculus*) and the alactaga (*Mus sagitta*) have their three middle metatarsal bones consolidated into one piece. The two lateral toes are distinct in the jerboa, but of comparatively small size; in the alactaga they are quite wanting.

Teeth. — The distinguishing character of the order of quadrupeds under consideration is the remarkable arrangement of their dental system, by which they are enabled to erode the hardest vegetable substances. The chief food of many genera, indeed, consists of the bark, wood, and even the hard fruits of trees, to devour which necessarily requires great strength of jaw, and such a disposition of their incisor teeth as to convert them into strong chisel-like cutting weapons, the edges of which never become blunted even to the latest period of life.

These incisor teeth, called also *dentes scalprarii*, are situated in the front of the mouth, and are generally two in number in each jaw, except in the genus Lepus, embracing the hares and rabbits, which possess two small additional incisors, situated behind each of the large ones contained in the upper jaw.

Between the incisors and the molar teeth there is a considerable vacant space, by which arrangement the play of the anterior chisels is much facilitated, their action being likewise materially assisted by the mode of articulation of the lower jaw, which allows of considerable movement from behind forwards, and by the great power of the pterygoid and masseter muscles. The molar teeth are likewise exceedingly strong, and vary considerably in their mode of implantation in the jaws of different genera.

The incisors* are always regularly curved, the upper ones describing a larger segment of a smaller circle, the lower ones a smaller segment of a larger circle; these are the longest incisors, and usually have their alveoli extended below or on the inner side of those of the molars to the back part of the lower jaw. Like the molars of the Megatherium, and other teeth of unlimited growth, the implanted part of the long and large incisors retains the form and size of the exposed part or crown to the widely open base, which contains a long, conical, persistent dentinal pulp, and is surrounded by the capsule in a progressive state of ossification as it approaches the crown, an enamel pulp being attached to the inner side of that part of the capsule which covers the convex surface of the curved incisor. The matrix is here noticed in connection with the tooth, because it is always found in full development and activity to the time of the Rodent's death. The calcification of the dentinal pulp, the deposition of the earthy salts in the cells of the enamel pulp, and the ossification of the capsule proceed contemporaneously; fresh materials being added to the base of the vascular matrix as its several constituents are progressively converted into the dental tissues in the more advanced part of the socket. The tooth thence projecting consists of a body of compact dentine, sometimes with a few short medullary canals continued into it from the persistent pulp cavity, with a plate of enamel laid upon its anterior surface, and a general investment of cement, which is very thin upon the enamel, but less thin in some Rodents, upon the posterior and lateral parts of the incisor. The substance of the incisor diminishes in hardness from the front to the back part of the tooth; the enamel consisting of two layers, of which the anterior and external is denser than the posterior layer, and the posterior half of the dentine being by a modified number and arrangement of the calcigerous tubes less dense than the anterior half.

The abrasion resulting from the reciprocal action of the upper and lower incisors pro-

* Owen, Odontography, p. 398.

duces accordingly an oblique surface, sloping from a sharp anterior margin formed by the dense enamel, like that which slopes from the sharp edge formed by the plate of hard steel laid upon the back of a chisel; whence the name dentes scalprarii given to the incisors of the Rodentia.

The varieties to which these incisors are subject in the different Rodents are limited to their proportional size, and to the colour and sculpturing of the anterior surface. Thus in the Guinea-pig, jerboa, and squirrel the breadth of the incisors is not half so great as that of the molars, whilst in the coypa they are as broad, and in the Cape mole rats (*Bathyergus* and *Orycteromys*) broader than the molars.

In the coypa, beaver, agouti, and some other Rodents, the enamelled surface of the incisors is of a bright orange or reddish brown colour. In some genera of Rodents, as orycteromys, otomys, meriones, gerbilla, hydrochærus, lepus, and lagomys, the anterior surface of the upper incisors is indented by a deep longitudinal groove. This character seems not to influence the food or habits of the species; it is often present in one genus and absent in another of the same natural family; in most Rodents the anterior enamelled surface of the scalpriform teeth is smooth and uniform.

The molar teeth are always few in number, obliquely implanted and obliquely abraded, the lateral series converging anteriorly in both jaws; but they present a striking contrast to the incisors in the range of their varieties, which are so numerous that they typify almost all the modifications of form and structure which are met with in the molar teeth of the omnivorous and herbivorous genera of other orders of Mammalia.

In some Rodents the molar teeth are rootless, like those of the wombat, the toxodon, and elasmothere; some have short roots tardily developed, like the molars of the horse and elephant; and some soon acquire roots of the ordinary proportional length.

The Rodents which have rootless molars comprise the families of the hares, chinchillas, Chili rats, and cavies; most of the voles, the houtias (*Capromys*), and the Cape jerboa (*Helamys*).

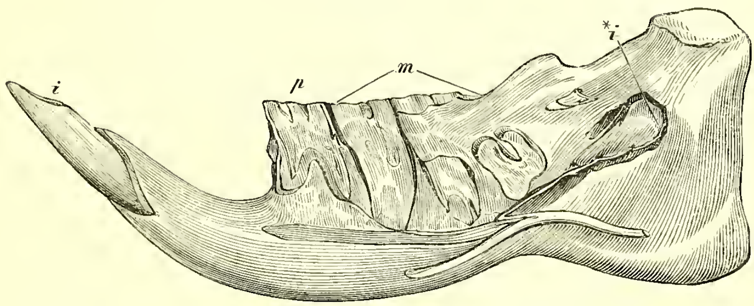
The genera which have molars, with short or incomplete roots, developed late, are *Castor* (beaver), *Hystrix* (porcupine), *Cœlogenys* (spotted cavy), *Dasyprocta* (agouti), *Spalax* (blind rat), *Myopotamus* (coypa), *Euryotis*, *Accomys*, and *Aplodontia*.

The families of the squirrels, dormice, rats, and jerboas have rooted molars.

The differences in the mode of implantation of the molar teeth relate to differences of diet. The Rodents, which subsist on mixed food, and which betray a tendency to carnivorous habits, as the true rats, or which subsist on the softer and more nutritious vegetable substance, as the oily kernels of nuts, suffer less rapid abrasion of the molar teeth; a minor depth of the crown is therefore needed to perform the office of mastication during the brief period of existence allotted to these active little mammals; and as the economy of nature is manifested in the smallest particulars as well as in her grandest operations, no more dental substance is developed after the crown is formed than is requisite for the firm implantation of the tooth in the jaw.

Rodents that exclusively subsist on vegetable substance, especially the coarser and less nutritious kinds, as herbage, foliage, the bark and wood of trees, wear away more rapidly the grinding surface of the molar teeth; the crowns are therefore larger, and their growth continues by a reproduction of the formative matrix at their base, in proportion as its calcified constituents, forming the exposed working part of the tooth, are worn away. So long as this reproductive force is active the molar tooth is implanted, like the incisor, by a long undivided continuation of the crown; when the force begins to be exhausted the matrix is simplified by the suppression of the enamel organ, and the dentinal pulp continues to be reproduced only at certain points of the base of the crown, which by their elongation constitute the fangs. The beaver and other Rodents in the second category of the order, according to the implantation of the molar teeth, exemplify the above condition; but in the capybara, dolichotis,

Fig. 267.



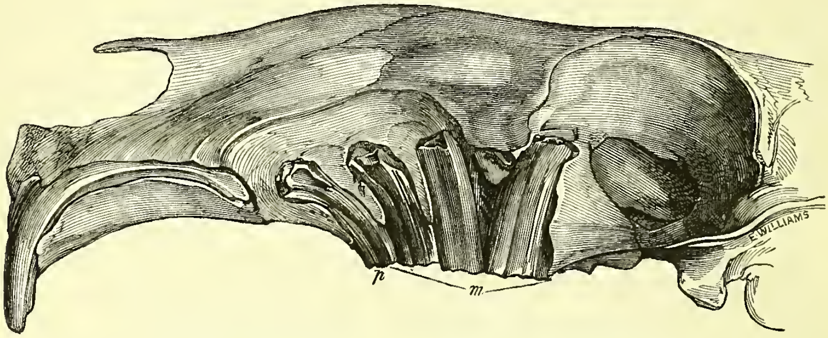
Lower jaw of the Porcupine (Hystrix cristata).

i, incisor tooth; *m*, the molar teeth, implanted in the jaws by means of fangs; *i**, pulp at the base of incisor tooth; *p*, anterior molar.

and other Rodents with rootless molars, the reproduction of the molar, like that of the incisor teeth, appears to continue throughout the animal's existence. The rootless and perpetually growing molars are always more or less curved; they derive from this form the same advantage as the incisors, in the relief of the delicate tissues of the active vascular matrix from the effects of the pressure which would otherwise have been transmitted more directly from the grinding surface.

The complexity of the structure of the crown of the molar teeth, and the quantity of enamel and cement interblended with the dentine, are greatest in the rootless molars of the strictly herbivorous Rodents. The crowns of the rooted molars of the omnivorous rats and mice are almost as simple as the tuberculate molars of the bear, or of the human subject, which they appear to typify. They are at first tuberculate; when the summits of the tubercles are worn off, the inequality of the grinding surface is for a time maintained by the deeper transverse folds of enamel, the margins of which are separated by alternate valleys of dentine and cement; but these folds, sinking only to a slight depth, are in time obliterated, and the grinding surface is reduced to a smooth field of dentine, with a simple border of enamel. A similar change in the grinding surface, consequent on age and use, is shown in the molars of the souslik, or ground squirrel; as also in those of the gerbille, and is common to all that possess roots. It will be seen that these folds have a general tendency to a transverse direction across the crown of the tooth. Baron Cuvier has pointed out the concomitant modification of the shape of the joint of the lower jaw, which almost restricts it to horizontal movements to and fro, in the direction of the axis of the head, during the act of mastication. When the folds of enamel dip in vertically from the summit to a greater or less depth into the substance of the crown of the tooth, as in those molars which have roots, the configuration of the grinding surface varies with the degree of abrasion, of which examples have already been cited; but in the rootless molars, where the folds of enamel extend inwards from the entire length of the sides of the tooth, the characteristic configuration of the grinding surface is maintained without variation, as in the Guinea-pig, the capybara, and the Patagonian cavy.

Fig. 268.



Upper jaw of the Patagonian Cavy (Chloromys Patagonica).

i, incisor tooth, laid bare throughout its whole length; *m, p*, molar teeth implanted without fangs into arched sockets.

The whole exterior of the molar teeth of the Rodentia is covered by a cement, and the external interspaces of the enamel folds are filled with the same substance. In the chinchillidæ and the capybara, where the folds of enamel extend quite across the body of the tooth, and insulate as many plates of dentine, these detached portions are held together by the cement; such folds of enamel are usually parallel, as in the large posterior lower molar of the capybara, which, in shape and structure, offers a very close and interesting resemblance to the molars of the Asiatic elephant.

The partial folds and islands of enamel in the molars of the porcupine and agouti, typify the structure of the teeth of the rhinoceros; the opposite lateral inflections of enamel in the molars of the gerbille and Cape mole-rat represent the structure of the molars of the hippopotamus; the double crescentic folds in the jerboa sketch out, as it were, the characteristic structure of the molars of the Anoplothere and Ruminantia.

Although, as has been shown, the molar teeth in many Rodents are rootless and of unlimited growth, as in the Edentata, in none is enamel absent; or vascular dentine, as the chief constituent of the tooth, present. These essential differences characterise the molars of those Rodents, which by use have their grinding surface reduced to a simple depression bounded by a raised circular margin, as in the great Cape mole; that margin being formed by true enamel, but in the sloths by hard dentine.

It is peculiar to some of the Rodents with rootless molars to have the sockets of these long curved teeth open at both extremities, so that, in the dry skull, the base of the tooth protrudes as well as the grinding surface; the matrix in such instances adheres to the peri-

osteum, which covered the portion of bone absorbed from the bottom of the alveolus. The jumping hare (*Helamys capensis*), when full grown, offers a good example of this curious structure.

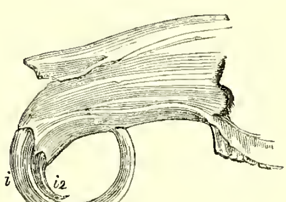
The molars are not numerous in any Rodents; the hare and rabbit (*Lepus*) have $\frac{6-6}{5-5}$; *i. e.* six molars on each side of the upper jaw, and five on each side of the lower jaw: the pika (*Lagomys*), has $\frac{5-5}{5-5}$; the squirrels have $\frac{5-5}{4-4}$; the families of the dormice, the porcupines, the spring rats (*Echingidæ*), the octodonts, chinchillas, and cavies, have $\frac{4-4}{4-4}$ molars; in the great family of rats (*Muridæ*), the normal number of molars is $\frac{3-3}{3-3}$; but the Australian water rat (*Hydromys*) has but $\frac{2-2}{2-2}$ molars, making with the incisors twelve teeth, which is the smallest number in the Rodent order; the greatest number of teeth in the present order is twenty-eight, which is exemplified in the hare and rabbit; but thirty-six teeth are developed in these species, six molars and two incisors being deciduous.

In all the Rodents, in which the number of molars exceeds three in a series, the additional ones are anterior to these, and are premolars, *i. e.* they have each displaced a deciduous predecessor in the vertical direction, and are what Cuvier calls *dents de remplacement*. This it is which constitutes the essential distinction between the dentition of the marsupial and the placental Rodent; the latter, like the placental Carnivora, Ruminantia, and ordinary Pachydermata having never more than three true molars. Thus the Rodents, which have the molar formula of $\frac{4-4}{4-4}$, shed the first tooth in each series; and this is succeeded by a permanent pre-molar, which comes into place later than the true molars; later, at least, than the first and second, even when the deciduous molar is shed before birth, as was observed by Cuvier in the Guinea-pig. In the hare and rabbit the three anterior teeth in the upper jaw, and the two anterior ones in the lower jaw, succeed and displace, in like manner, deciduous predecessors, and come into place after the first and second true molars are in use, and contemporaneously with the last molar.

It does not appear that the scalpriform incisors are preceded by milk teeth, or, like the pre-molars of the Guinea-pig, by uterine teeth; but the second incisor was observed by Cuvier to be so preceded in the genus Lepus, and he has figured the jaw of a young rabbit, before that deciduous tooth was shed, when six incisors are present in the upper jaw. This condition is interesting, both as a transitory manifestation of the normal number of incisive teeth in the Mammalia series, and as it elucidates the disputed nature of the great anterior scalpriform teeth. Geoffroy St. Hilaire contended that the scalpriform teeth of the Rodents were canines, because those of the upper jaw extended their fang backwards into the maxillary bone, which lodged part of their hollow base and matrix. But the scalpriform teeth are confined exclusively to the intermaxillary bones at the beginning of their formation; and the smaller incisors, which are developed behind them in our anomalous native Rodents, the hare and rabbit, retain their usual relations with the intermaxillaries, and, a fortiori, prove the tooth which projects anterior to them to be also an incisor.

The law of the unlimited growth of the scalpriform incisors is unconditional, and constant exercise and abrasion are required to maintain the normal and serviceable form and proportions of these teeth. When, by accident, an opposing incisor is lost, or when by the distorted union of a broken jaw the lower incisors no longer meet the upper ones, as sometimes happens to a wounded hare, the incisors continue to grow until they project like the tusks of the elephant, and the extremities, in the poor animal's abortive attempts to acquire food, also become pointed like tusks: following the curve prescribed to their growth by the form of their socket, their points often return against some part of the head, are pressed through the skin, then cause absorption of the jaw-bone, and again enter the mouth; rendering mastication impracticable, and causing death by starvation. In the Museum of the College of

Fig. 269.



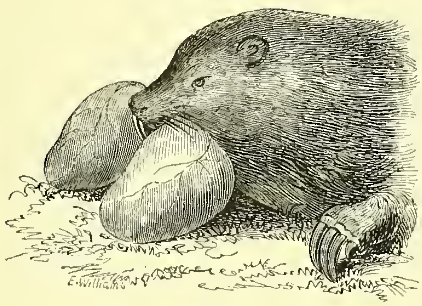
Incisor teeth of the upper jaw of a Rabbit, showing the effects of unchecked growth on the scalpriform incisor (*i*), *and the accessory incisor* (*i*, 2).

Surgeons there is a lower jaw of a beaver in which the scalpriform incisor has, by unchecked growth, described a complete circle; the point has pierced the masseter muscle and entered the back of the mouth, passing between the condyloid and coronoid processes of the lower jaw, descending to the back part of the molar teeth, in advance of the part of its own alveolus, which contains its hollow root. The upper jaw of a rabbit with an analogous abnormal growth of the scalpriform and accessory incisors is represented in *fig.* 269.

Organs of digestion. — The order of Rodent quadrupeds comprehends animals which are nourished by various kinds of food, both animal and vegetable substances forming the nutriment of some genera, whilst others live exclusively upon the fruit, bark, or leaves of

trees, or upon tender succulent plants. The differences observable in the structure of the stomach and intestinal canal correspond to the variety of their food, and bear a relation to the structure of their dental apparatus.

Fig. 270.



Cheek pouches of the Canada Rat (*Geomys bursarius*).

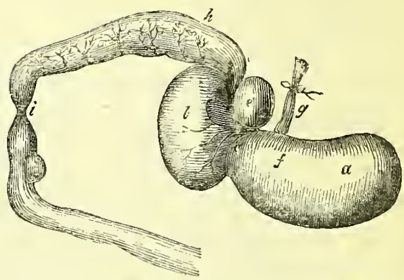
Some genera, as, for example, the Canada rat (*fig.* 270.) are remarkable for the possession of capacious cheek pouches, in which considerable quantities of food can be stored up, and which, like the crop of birds, may be considered as reservoirs, wherein nutriment can oe retained preparatory to its introduction into the stomach.

The type of *stomach* most common in this order is the following: the stomachal bag is formed by two distinct pouches, which are more or less separated from each other; one portion, situated to the left of the cardia, is placed longitudinally, and is generally of a cylindrical or conical shape. This portion is frequently larger than the right portion; it is lined internally with a thick epidermis, which terminates suddenly, and clearly indicates by its margin the boundaries of this compartment of the stomach. The right compartment, which is situated more transversely and further back, is of a conical shape, the apex of the cone terminating at the pylorus. This second portion has its walls thicker and more muscular than the former; its mucous membrane is not lined with epidermis, but presents the ordinary appearance. The distinction between these two portions is indicated externally by a constriction. The œsophagus enters the first compartment very near to the point where it communicates with the second.

Such may be said to be the typical form of the stomach in this extensive order, but many families recede from it to a greater or less extent.

In the squirrels (*Sciurus*) for example, the stomach is not divided into separate cavities, but is of a pyriform or oval shape, giving off a conical or cylindrical portion, which terminates in the pylorus. The first compartment is lined internally with a thick epidermis, which forms two oval lips, as it is prolonged around the opening into the second compartment, the lining membrane of which is simply mucous, without any apparent epidermic covering. The ondatras (*Fiber*, Cuv.), campagnols (*Arvicola*), and the lemmings (*Georychus*, Illiger), present a similar arrangement.

Fig. 271.



Stomach of the Water Vole (*Arvicola amphibius*).

g, œsophagus; *a*, *f*, cardiac extremity of the stomach; *c*, its median constriction; *b*, dilated pyloric extremity of ditto; *e*, pyloric pouch; *h*, *i*, duodenum.

In the Hudson's Bay lemming (*Mus Hudsonius*, Gm.), the shape of the stomach is slightly different, it is situated transversely and much elongated, without any division into cavities; the cardia opens at about the upper third of its anterior border; the left cul-de-sac is cylindrical and of uniform size with the pyloric portion, which is bent forward and to the left side.

The stomach likewise varies from the common type in the jerboa (*Dipus*, Gm.), and in the leaping hares of the Cape (*Helamys*). In the former it is globular, in the latter pyriform and longitudinal, with a large cardiac cul-de sac directed forwards, a pyloric cul-de-sac, and a short cylindrical pyloric portion, which is bent forwards.

The rat moles (*Spalax*, Guldensledt) are approximated to the lemmings and to the campagnols in the shape of their stomach, which is divided into two pouches, having the œsophagus closely approximated to the pylorus.

In the muscardin (*M. avellenarius*, L.) the stomach offers a peculiarity in its structure, which distinguishes it not only from the other species of this genus, but also from all other Mammalia, — the œsophagus immediately beyond the diaphragm terminates in a globular pouch, the walls of which are thick, glandular, and exhibiting internally numerous pores leading into crypts: this structure is separated by a constriction from the stomach properly so called. This latter organ forms a large cul-de-sac of a slightly oval shape, which gives off anteriorly, and to the right side, a short bowel-like pyloric portion. In this animal, therefore, there are two stomachs, one of which corresponds with the glandular stomach of birds, as will be seen further on. The beaver exhibits traces of this structure.

The stomach of the hamster (*Cricetus*, Cuv.) approximates the common type described above, the stomach being divided into two pouches, separated by a deep constriction; the left pouch is cylindrical, the right globular. The cardiac orifice is situated in

the former to the right of its base, opening on the constriction itself, so that aliments can pass immediately into the second compartment by the assistance of a fold, which is prolonged from the cardia into this cavity; and the pyloric portion may be distinguished, which is more muscular than the rest, and terminates in the intestine by a slightly prominent pylorus.

The Cape mole (*Bathiergus*, Iliger) likewise conforms to the preceding type of structure; the left compartment of the stomach is of enormous size, elongated and pierced at its base by the cardiac orifice; the left compartment is of smaller dimensions, of a globular form, and separated from the preceding, both by an external constriction and an internal fold of the mucous membrane. There are, moreover, two additional folds nearer to the pylorus, which seem to form a third compartment. The orycteres of the Downs (*Bathiergus maritimus*) has its stomach slightly different; its position is more longitudinal, so that the left compartment is anterior, and the right posterior; the pyloric portion short, cylindrical, and directed forwards.

In the beaver (*Castor*) the stomach is transverse and elongated in that direction, the right portion being larger than that which is situated to the left of the cardia; the œsophagus is inserted into the first third of its anterior margin by a narrow opening, surrounded with pointed processes, which are analogous to the fringes formed by the epidermis in many other Rodents. At the point where it terminates around the opening of the first compartment of the stomach into the second, numerous largely developed culs-de-sac are distinguishable, which project more or less beyond the cardia in different individuals. On the right of this orifice commences the pyloric portion, the termination of which is indicated by an external constriction, and by an internal thickened ring. The pylorus is approximated very closely to the cardiac orifice. This pyloric portion, which is more muscular than the rest, is sometimes dilated into a distinct pouch, separated by a constriction from the pyloric cul-de-sac. The internal membrane presents every where the same appearance, except that in the pyloric portion it appears to be more smooth, and its folds take a different direction. On the right of the cardia there is a very thick fold, separating the left from the right compartment.

In the rabbit and the hare (*Lepus*, Lin.) the stomach is very much elongated, particularly in that portion which is situated to the right of the cardiac orifice. This latter portion forms a bulb, the muscular wall of which is thicker than elsewhere, especially in the vicinity of the pylorus, where it is swollen into a muscular ring. In the other parts of the stomach the existence of this layer is scarcely perceptible.

In the lagomys (Cuv.) we have again the common type of structure, as also in the agoutis and the pacas.

In the pteromys (F. Cuv.) the stomach is situated more transversely, and the two culs-de-sac are more distinct; the right compartment is the largest, and gives off at an angle a short conical pyloric portion.

In the sciuropteres (F. Cuv.) the stomach is round, deep from before to behind, and having the bottom of the cardiac culs-de-sac formed into a little pouch, and extending slightly beyond the cardia; the pyloric portion is conical, very muscular, and lined internally with a yellowish mucous membrane, whilst the lining membane of the rest of the stomach is white and arranged in folds, which form arches parallel to the curvatures of the viscus. There are two other folds running longitudinally on the right and on the left of the cardia, but which probably do not exist when the stomach is distended: these would seem to indicate traces of a division of the cavity into three pouches.

In the dormice (*Myoxus*, Gm.) the stomach differs in shape in accordance with the appetites of the different species. In the common dormouse (*Mus Glis*, Lin.) it is conical, with a small pyloric portion directed forwards; its membranes are thick and muscular, approximating the type of a carnivorous stomach. In *Myoxus Nitela*, on the contrary, it is globular, and consists of a single sac; the crypts, the orifices of which open into the cavity of the stomach, form a thick disc in the vicinity of the cardia: these crypts are evidently small culs-de-sac, formed by the mucous membrane and the cellular layer beneath it, which here appear folded upon themselves in irregular festoons, when a section of this glandular disc is examined. The ligneous substances upon which the beavers feed have rendered necessary this superabundance of the secretions furnished by this gland. A constriction separates the pyloric portion from the remainder of the straight part of the stomach. The pylorus consists of a prominent ring projecting into the intestine.

In the family of the porcupines (*Hystrix*, Lin.) we have another example of the differences which the stomach may present in different genera. In the cuendu (*Synetheres*, F. Cuv.) this viscus resembles that of the orycteres of the Downs, above described; it is elongated, longitudinal, with one compartment anterior and the other posterior; the œsophagus is inserted into the right side; the cardia is placed far back, and approximated to the pylorus; the pyloric portion is short, cylindrical, and directed forwards, terminating by a ring, which projects into the intestine. In the European porcupine (*Hystrix cristata*, Lin.) the stomach is globular, forming from before to behind a deep and wide bag.

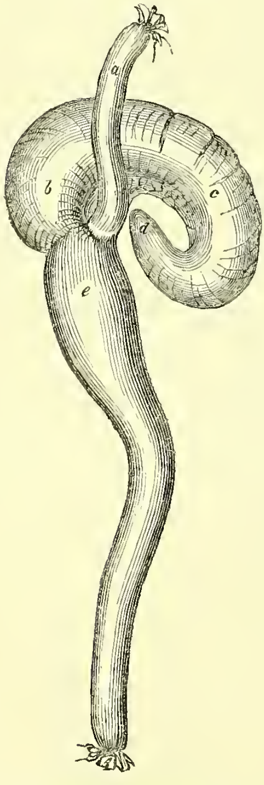
Intestinal canal.—The tract of the small intestines offers nothing remarkable in the Rodentia; its walls are very thin, and its diameter pretty even throughout. On coming to the large intestines, the most striking feature is the enormous size of the cæcum, which, in many genera, itself fills up a great proportion of the abdominal cavity. There are, moreover, many interesting modi-

fications to be noticed, both in the construction of the cæcum and of the commencement of the colon, which generally presents the same appearance as the cæcum itself for a short distance from its commencement.

The greater or less development of the cæcum is in relation to the nature of the food appropriate to each individual. In one genus only, namely, the dormouse (*Myoxus*), it is altogether wanting; those Rodents that live upon grass and herbs have it most remarkably developed; and in the hare it has been calculated that the capacity of the cæcum is ten times as great as that of the stomach itself. In the granivorous genera its size is likewise very considerable; so that, in the hamsters, lemmings, Guinea-pigs, and allied genera it has been estimated to be four times larger than the stomach.

Another remarkable peculiarity may be observed in the cæcum of the Rodentia, namely, that it frequently has its cavity divided into regularly arranged cells disposed in several rows, or else forming a single series. In other cases the cavity of the cæcum is divided into compartments by a broad spiral

Fig. 272.



Cæcum of the Squirrel.

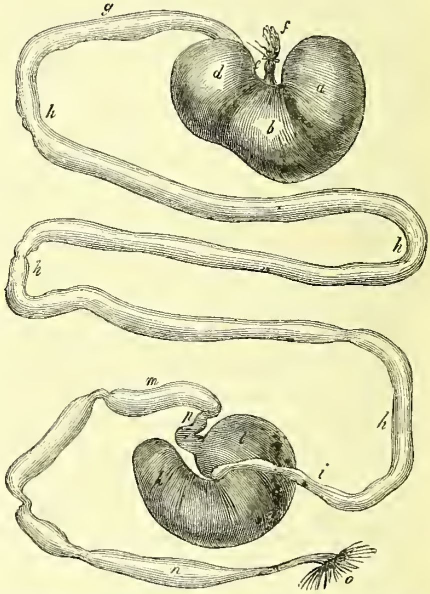
a, termination of the small intestine; *b*, *d*, the cæcum; e, dilated commencement of the colon.

valve, as is the case in the hares; or, as in the marmots, by circular folds of its lining membrane. In some species again, as in the jerboa, &c., the interior of the cæcum is a simple cavity, without any division or internal complication. All these diversities of structure seem to be in relation with the different kinds of food devoured by these animals.

The proportionate length of the small intestine as compared with that of the large, is frequently the reverse of what holds good in carnivorous quadrupeds; but the diameter of the latter, except in the immediate vicinity of the cæcum, is scarcely greater than that of the small intestine (*fig.* 273. *m*, *n*).

The intestinal villi have the shape of leaflets of fringed laminæ, or sometimes of very fine filaments; the entire inner surface of the small intestine is villous, whilst that of the large intestine is quite smooth.

Fig. 273.



Stomach and intestinal canal of the Rat (*Mus Rattus*).

f, œsophagus; *a*, *b*, *d*, compartments of the stomach; *e*, pylorus; *g*, *h*, *i*, small intestine; *k*, *l*, cæcum; *p*, commencement of the colon; *m*, *n*, colon; *o*, anus.

It is worthy of observation that in those species that have the cæcum most largely developed, that organ is furnished with very remarkable glandular appendages; this structure is met with in the genera *Lepus* and *Lagomys*.

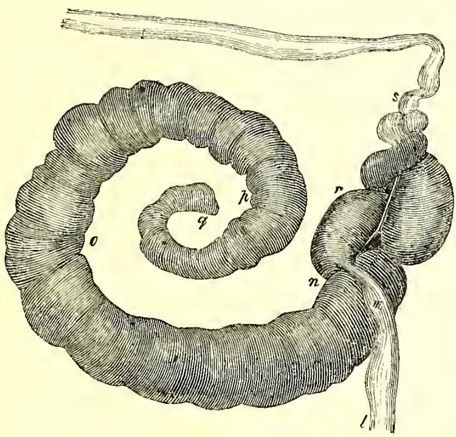
In order to illustrate the above general description of the digestive organs of the order of quadrupeds under consideration, we shall select a few examples illustrative of the principal varieties which it presents in different genera.

In the squirrel (*Sciurus*) the small intestine (*fig.* 272. *a*) is nearly of the same diameter throughout; the cæcum (*b*, *c*, *d*) is of moderate dimensions, of a conical shape, and destitute of any cells or partitions internally.

The colon (*e*) is for a short distance almost of the same diameter as the cæcum, but it soon diminishes in size, and throughout the rest of its extent is scarcely wider than the small intestine. Internally, it presents no septa or valvulæ conniventes. The intestinal papillæ form small lamellæ, the borders of which are fringed with delicate filaments; these papillæ extend throughout the whole length of the small intestine, but towards its termination becomes smaller and less perceptible.

In the rats, the alimentary canal would be nearly of the same calibre throughout, were it not for the interposition of the cæcum between the ileum and the colon. The cæcum in this family of Rodents rather resembles a second stomach (*fig.* 273. *k*, *l*) than a bowel; it is capacious, short, and slightly curved upon itself, but without any constrictions, tapering gradually towards its blind extremity. The walls of the intestinal canal are throughout thin, delicate, and transparent;

Fig. 274.



Cæcum of the Water Vole (Arvicola amphibius).

l, *m*, end of the small intestine; *n*, *o*, *p*, *q*, cæcum; *r*, dilated commencement of the colon; *s*, point at which the colon becomes contracted.

but slight traces of a spiral valve are visible at the commencement of the colon.

In the water-rat (*Arvicola amphibius*) the small intestines are of equable diameter throughout their whole extent, but their calibre is small, as indeed is that of the large intestine. The cæcum is, however, of enormous proportions (*fig.* 274. *n*, *o*, *p*, *q*), and is divided at intervals into pouches by deep constrictions. The commencement of the colon (*r*) is extremely voluminous, but it soon diminishes in its diameter, and is twisted in a remarkable manner, so as to form several close spiral turns; the walls of the small intestine (*l*, *m*) are very thin and transparent; at the commencement of the colon its lining membrane is thrown into regular folds, which, as they appear through the transparent coats of the intestine, resemble a series of spiral muscular fibres.

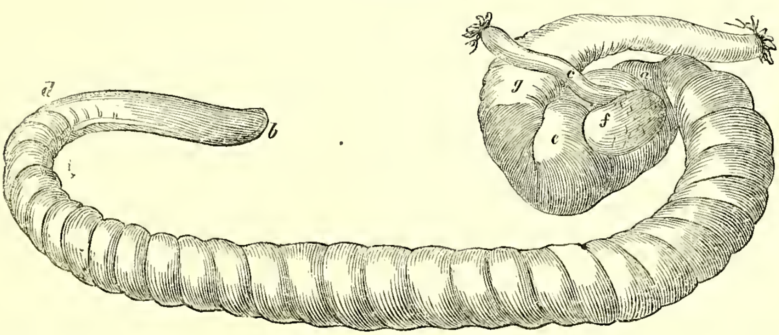
In other species belonging to the genus arvicola, the same disposition is observable.

In the Cape moles (*Bathiergus*) the structure of the cæcum varies. In the orycterus of the Downs (*Bathiergus maritimus*) the cæcum is short, and has its walls sacculated and puckered up, as it were, by tendinous bands. The colon begins by a wide pouch, and preserves through nearly its whole length a considerable diameter and sacculated appearance, but on approaching the anus it becomes contracted and of equable diameter.

In the white-spotted orycterus (*Bathiergus capensis*) the cæcum is much longer in proportion and of more equal calibre, although still very wide, in proportion to the size of the small intestine, and much sacculated; the commencement of the colon is at first of the same diameter as the cæcum, but it soon becomes narrower and spirally convoluted, much in the same way as in the water-rat.

In the hare and in the rabbit the small intestine is nearly of the same diameter throughout its whole length; the cæcum is of a very remarkable size, and forms an enormous elongated conical sac, divided, at intervals, by deep constrictions into numerous compartments, as far as about the distance of two or

Fig. 275.



Cæcum of the Hare.

c, termination of the ileum; *a*, *d*, a spirally convoluted cæcum; *b*, *d*, its terminal glandular portion; *f*, dilated pouch, close to the termination of the small intestine; *e*, capacious commencement of the colon which, at *g*, becomes considerably diminished in size.

three inches from its extremity (*fig.* 275.). The constrictions, apparent externally, correspond to the windings of a spiral valve, which runs nearly along the whole length of its cavity. The small intestine, at the point where it is about to enter the colon, dilates into a cavity (*f*), the walls of which are thick and glandular. At its commencement (*e*) the colon is quite as capacious as the cæcum, but it soon begins to contract in its diameter. (*g*) At its commencement there are three rows of sacculi, divided by as many tendinous bands, but further on these sacculi disappear. The rectum is much dilated, and contains, at intervals, small pellets of excrement moulded in the sacculi of the colon. In all the species belonging to this genus, as well as in the rats and hares, including the *Lagomys*, the extremity of the cæcal bag, opposite to that which receives the termination of the small intestine, is terminated by a long, smooth, cylindrical appendage (*fig.* 275. *d*, *b*) the walls of which are glandular, and somewhat resemble those of the glandular stomach of a bird.

The above examples will suffice to put the reader in possession of the general structure of the alimentary canal in the rodent order of quadrupeds; and for farther details we must refer him to the last edition of Cuvier's Leçons d'Anatomie comparée, where the principal varieties met with in the different genera are recorded.

Liver.—In the Rodentia the liver is very largely developed, and presents the usual division into five principal lobes. The gall-bladder, though generally present, is sometimes wanting, a circumstance more particularly observable in the family of rats. Another circumstance which may be noticed is that the bile is frequently poured into the intestine at a point remote from that where the pancreatic fluid enters it; when such is the case, the biliary secretion enters the duodenum very near to the pylorus, above the entrance of the pancreatic duct.

In the porcupine the ductus communis choledochus is formed by the union of two hepatic canals with the cystic duct; it enters the intestine close to the pyloric ring, opening into a furrow excavated in the latter, in such a manner that the bile would seem to flow as easily into the stomach as into the duodenum. The opening of the pancreatic canal is at a considerable distance from the pylorus.

The *pancreas* is very large, and generally divided into two portions.

The *spleen* occupies its usual position suspended from the stomach by the *gastro*-splenic omentum.

The *lymphatic system* of the Rodentia conforms in all respects to the usual arrangement of these vessels met with in other quadrupeds, and exhibits nothing worthy of particular remark.

The *arterial system*, as far as the general distribution of the blood-vessels is concerned, offers a few peculiarities worthy of notice. In all those genera of rodent quadrupeds which become dormant during the winter months, the vertebral artery considerably surpasses in size the internal carotid; to such an extent, indeed, that some authors have described the latter vessel as being entirely wanting. In this case the basilar artery forms by itself a very considerable part, and sometimes the whole of the circle of Willis, giving off the anterior cerebral arteries as well as the posterior arteries of the brain.* The arrangement of the carotids, moreover, varies remarkably in different genera.

In the beaver the internal carotid is larger than the vertebral.

In the porcupine the internal carotid, after following for some distance the direction of the internal maxillary, without undergoing any sinuous flexures, enters the cranium through the foramen lacerum anterius, where it immediately joins with the basilar, which surpasses it in size, to form the circle of Willis.

In the Guinea-pig and the agouti there is, properly speaking, only an external carotid, of which the internal carotid is but a small branch. This little cerebral branch is derived from the internal maxillary, of which it seems to be a continuation; it enters the cranium through the foramen ovale of the sphenoid bone, and joins the circle of Willis, which is here principally formed by the vertebral artery.

In the squirrel the internal carotid enters an osseous canal in the tympanum, through the jugular foramen, passes between the crura of the stapes, and then penetrates the cranium through a hole in the petrous portion of the temporal bone; it there divides into two branches, the smaller of which enters a deep groove in the os petrosum, issues from the cranium through the foramen lacerum anterius to enter it again through the oval foramen of the sphenoid bone. It is only after all these windings that it divides into small branches, and of these only one or two go to form the circle of Willis, the rest being meningeal arteries. The continuation of this branch subsequently becomes the representative of a portion of the ophthalmic artery. The other branches usually given off from the ophthalmic artery are derived from the second branch of the internal carotid above mentioned, which previously gives off branches to the dura mater. It will thus be seen that the internal carotid supplies very little blood to the brain, and this blood only arrives at its destination by a very circuitous route.†

In the marmot the internal carotid at first follows the same course as in the squirrel; it enters the canal of the tympanum through the jugular foramen, and then traverses the opening between the crura of the stapes, after which it divides into two branches: of these the internal, which is the smallest, runs

* *Vide* Mémoire sur les vaisseaux céphaliques de quelques mammifères qui s'en courdissent pendant l'hiver, par M. Otto, Annales des Sc. Natur. t. xi. p. 200.

† *Vide* Barkow, Disquisitiones circa originem et decursum arteriarum animalium. Lipsiæ, 1829.

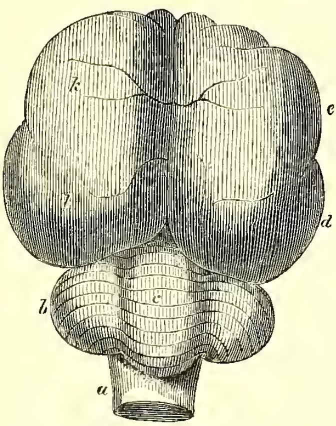
through an ascending canal, which enters the cavity of the skull close to the sella turcica, arriving at the brain much in the same manner as the internal carotid of the human subject. This branch is smaller than the vertebral artery. The other or external branch enters the cranium through a canal that opens upon the anterior surface of the petrous bone, and divides into the middle meningeal and ophthalmic arteries.

In the dormouse the distribution of the internal carotid very nearly resembles what is described above, as occurring in the squirrel and in the marmot. In some genera of Rodents the internal condyle of the os humeri is perforated by a canal through which the ulnar artery passes in company with the median nerve: this arrangement exists in the squirrel, the hamster, and the helamys.

Venous system.—In most of the Rodentia, instead of a single anterior vena cava, there are two principal anterior trunks of the venous system, one of which, namely the right, occupies the usual position of the vena cava anterior, whilst the left runs along the furrow that separates the base of the ventricle of the heart from the left auricle, to reach the right auricle, into the upper and left side of which it opens.

In those genera which hibernate the external jugular vein likewise presents a very remarkable arrangement. This vein receives a considerable proportion of the blood derived from the brain through a wide canal, situated between the os petrosum and the temporal bone, into which the anterior division of the transverse sinus opens, so that it is only the smallest moiety of blood derived from the vein which escapes through the jugular foramen into the internal jugular. The vertebral vein likewise communicates with the external jugular, carrying off its share of the blood from the interior of the cranium.

Fig. 276.



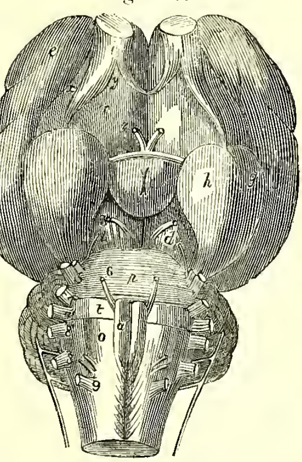
Upper surface of the brain of the Porcupine. (*After Serres.*)

a, medulla spinalis; *b*, hemispheres of cerebellum; *c*, median lobe of the cerebellum; *d*, *e*, *k*, *l*, cerebral hemispheres.

Although this disposition of the cerebral veins is common to all hibernating animals, as Cuvier very justly remarks, it is by no means peculiar to quadrupeds that pass the winter in a state of torpor; on the contrary, it is met with in many Rodents that do not hibernate; as, for example, in the rats; it also occurs in the horse, as well as in many *Edentata*, *Ruminantia*, and *Carnivora*. Cuvier believes this arrangement to be in relation with the situation and direction of the head, the difference between these quadrupeds and man rather depending upon the position of the latter standing on four legs, than upon any cause connected with the habit of hibernation.

Nervous system.—The brain in the Rodent order of quadrupeds presents two principal forms; in the feebler, and more strictly herbivorous species, such as the hare, the rabbit, the agouti, paca, &c., it presents a great resemblance externally in its shape to that of birds, the cerebral hemispheres being broad behind, and gradually tapering towards the anterior lobes. In others, such as the beaver, porcupine, capromys, &c., the contour of the brain is nearly circular (*fig.* 276.), as in carnivorous quadrupeds. Between these extreme forms there are, however, intermediate gradations, such as are met with in the squirrel, the marmot, the water-rat, and others.

Fig. 277.



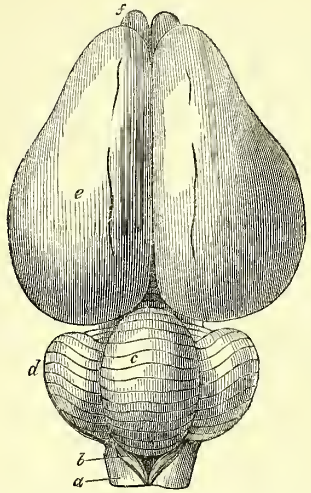
Base of the brain of the Porcupine (*Histrix cristata*). (*After Serres.*)

a, anterior pyramid, exhibiting the interlacement of their internal fasciculi; *o*, olivary bodies; *t*, trapezoid bodies; *p*, pons Varolii; *h*, the lobe of the hippocampus; *g*, middle portion of the hemisphere; *r*, olfactory tract; *x*, external root of olfactory lobe; *y*, internal root of ditto. The nerves are indicated by corresponding numbers.

The most striking circumstance presented by the brains of these animals is the almost complete deficiency of cerebral convolutions. The hemispheres are almost completely smooth upon their surface, presenting only a few shallow lines instead of the numerous sulci which characterise the brain of the Carnivora.

The cerebellum is of moderate proportions, and is scarcely at all overlapped by the posterior lobes of the cerebrum.

Fig. 278.

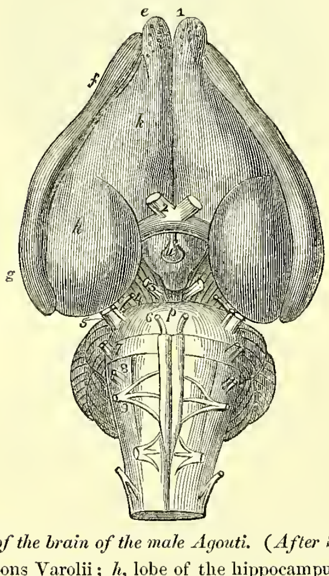


Upper surface of the brain of the male Agouti. (After Serres.)

a, the medulla spinalis; *b*, posterior pyramid; *c*, median lobe of the cerebellum; *d*, hemisphere of cerebellum; *e*, cerebral hemispheres; *f*, olfactory lobe of the brain.

On separating the hemispheres, the tubercula quadrigemina (*fig.* 280. 8, 9) are seen to be of very large size; and, what is remarkable, the anterior pair (*nates*) are of a roundish form, and much larger than the posterior pair (*testes*) (8); a circumstance which is the converse of what exists in carnivorous quadrupeds. In other respects the structure of the brain in the Rodentia offers no peculiarity worthy of special notice.

Fig. 279.

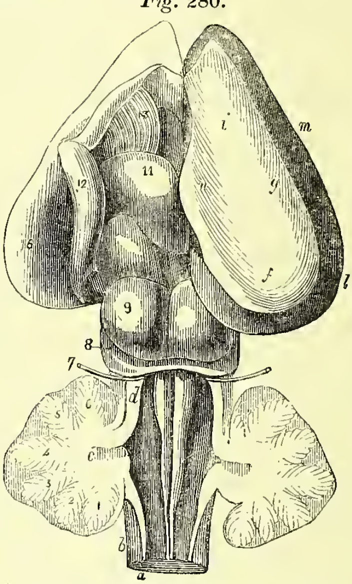


Base of the brain of the male Agouti. (After Serres.)

p, pons Varolii; *h*, lobe of the hippocampus; *g*, *f*, lateral portion of cerebral hemisphere; *k*, anterior part of the lobe of the hippocampus; *e*, olfactory lobe; *u*, infundibulum. The nerves are indicated by corresponding numbers.

The organs of the senses conform strictly in their anatomical structure to the general type common to mammiferous quadrupeds, and consequently need not occupy our attention in this place.

Fig. 280.



Interior of the brain of the same animal. (After Serres.)

a, medulla spinalis; *b*, restiform body; *c*, arbor vitæ cerebelli; 1, 2, 3, 4, 5, 6, ramifications of ditto; *d*, superior peduncle of the cerebellum; 7, nervus patheticus; 8, posterior quadrigeminal tubercle; 9, anterior quadrigeminal tubercle; 11, optic tract; 12, posterior pillar of the fornix; 13, corpus striatum; *n*, corpus callosum; *i*, *f*, *g*, horizontal section of the hemisphere on a level with ditto; *l*, *m*, lateral portion of the cerebral hemisphere.

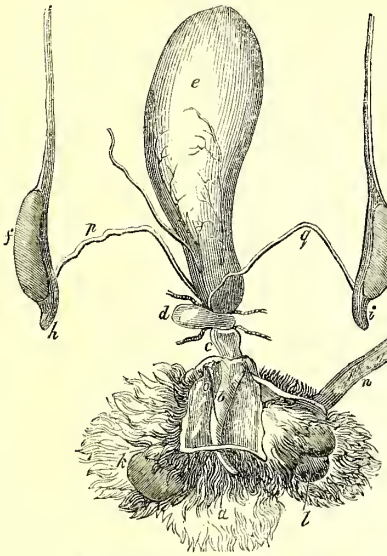
The structure of the *kidneys*, and the general disposition of the urinary apparatus afford nothing deserving particular description.

Male organs of generation.— The Rodentia are amongst the most prolific of all quadrupeds; a circumstance which may, perhaps, account for the extraordinary development of the appendages to the male generative system, which are met with throughout the order. It is, indeed, difficult to identify the precise analogies of some of the accessory genital organs, which are much more complex in structure than those of other Vertebrata.

In the greater number of Rodents, as for instance in the rats, the Guinea-pigs, the agoutis, the porcupines, the beaver, the ondatra, and the squirrels, the testicles are not contained in a scrotum, but during the season of impregnation are lodged beneath the skin of the perineum, which is tightly stretched over them. In the hares, however, two distinct scrotal pouches exist (*fig.* 281. *k*, *l*), situated in the vicinity of the anus, in which

the testes are contained. The testes are moreover, remarkable for tneir great size,

Fig. 281.



Male generative organs of the Hare.

a, glans penis; *b*, body of penis; *c*, prostate gland; *d*, vesiculæ seminales; *e*, the urinary bladder; *f*, *g*, testicles; *h*, *i*, epididymis; *k*, *l*, the two scrotal pouches; *p*, *q*, vasa deferentia.

which generally exceeds that of the kidneys; a circumstance which is more remarkably evident during the season of copulation.

From the testicles situated as above, the *vasa deferentia* ascend into the abdominal cavity, along with the spermatic vessels, through the external abdominal ring. In some tribes, a little above their insertion, the walls of the vasa deferentia become manifestly thicker, and the cavity of their duct considerably dilated; in some cases they join together, and seem to form but one canal; but this appearance is merely external, the ducts continuing separate throughout their whole length.

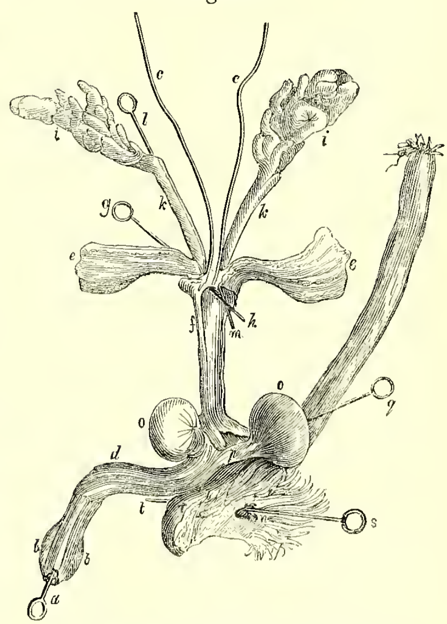
The *vesiculæ seminales*, or their analogues, exist in all the Rodentia. In the hares they are simple bags (*fig.* 281. *d*); but, generally speaking, their cavity is more or less convoluted, or branched out into cæca, as, for example, in the agouti (*fig.* 282. *i*, *i*), and in the beaver (*fig.* 284. *o*, *p*). In most of the genera of this order of quadrupeds the vesiculæ seminales are remarkable for their great development; in the Guinea-pig they form two long conical tubes, which tap.r much towards their extremities, but are slightly sacculated for a portion of their length; the excretory ducts in this animal open into the urethra by an orifice common to them, and to the vasa deferentia.

In the agouti each opens separately into the common cavity of the verumontanum, in which are also situated the separate orifices of the vasa deferentia, and of the excretory canals of the accessory vesicles; so that all these canals are brought into communication by means of this chamber.

In the Alpine marmot, the vesiculæ seminales contain internally a very complicated cavity, the walls of which are glandular.

In the rats, properly so called, the vesiculæ seminales consist of large membranous bladders of a flattened conical form, with their inner margins sacculated and uneven, something like a cock's comb. In these animals they are in great part situated out of the pelvis on account of their very la ge size; in the hamsters, the voles (*Arvicolæ*), the dormice, and the jerboas they present a similar structure, and become remarkably developed during the season for copulation.

Fig. 282.



The generative organs of the male Agouti.

a, a stylet introduced into the cul-de-sac, at the extremity of the penis; *b*, *b*, serrated bony plate, situated on each side of the glans penis; *c*, *c*, vasa deferentia; *d*, the body of the penis; *e*, *e*, the prostates; *f*, canal of urethra laid open; *g*, *h*, a style introduced through the prostatic duct into the urethra; *i*, *i*, the vesiculæ seminales; *l*, *m*, a wire passed along their duct *k*, into the urethra; *o*, *o*, Cowper's glands, communicating with the urethra by means of the duct, *p*, into which a style *q* has been passed; *n*, the anus; *r*, anal gland with the style, *s*, *t*, passed into its duct.

In the hare and in the rabbit these organs are represented by the single sac already alluded to (*fig.* 281. *d*), the size of which is considerable; this sac is of a triangular shape, two of its three corners being sometimes considerably elongated; its walls are membranous, except for about two thirds of its upper side, where they are formed by a thick glandular substance something resembling in texture the prostate gland. This sac opens into the urethra by a single orifice excavated in the centre of the verumontanum, which receives

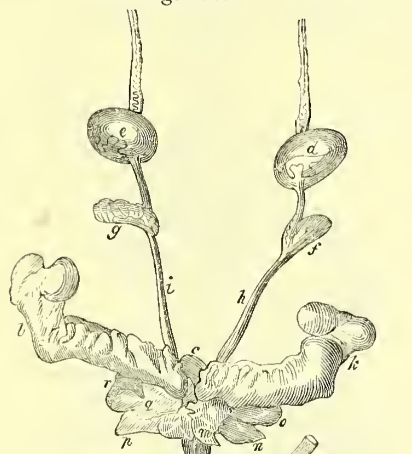
likewise the terminations of the two vasa deferentia.

In the lagomys (*Lepus pusillus, ogotonus,* and *alpinus,* Pall.) the vesiculæ seminales are double and separate.

In the common squirrel each seminal vesicle consists of a short canal folded upon itself. This approximates its fellow on the opposite side between the prostate and the canal of the urethra ; and, contrary to what is usual in this order, internal to the vasa deferentia.

The prostate glands. — The name of prostate gland is restricted by Cuvier to those glandular masses of analogous structure to the human prostate, the excretory canals of which open by one or several orifices into the commencement of the muscular portion of the urethra, or into the first portion of that canal. In some cases, however, the representatives of the prostate are made up of numerous ramified and complicated tubes, in which case they are called *tubular prostates.* In the hare and the rabbit, this gland is represented by the glandular mass, which, as above described, forms a portion of the walls of the vesiculæ seminales, and which extends for some distance upon the muscular portion of the urethra (*fig.* 281. *c*).

Fig. 283.



Male organs of the Water Vole (*Arvicola amphibius*).

a, glans penis; *c*, the urinary bladder; *d, e,* the testicles; *f, g,* epididymis, situated at some distance from the testes; *k, l,* vesiculæ seminales; *m, n, o, p, q, r,* the prostates; *s,* the rectum, the extremity of which is surrounded by a glandular mass, *t,* from which a milky fluid is poured into the rectum in the vicinity of the anus, *v.*

In the Alpine marmot it forms a considerable mass situated above the commencement of the urethra, divided posteriorly into two roundish lobes.

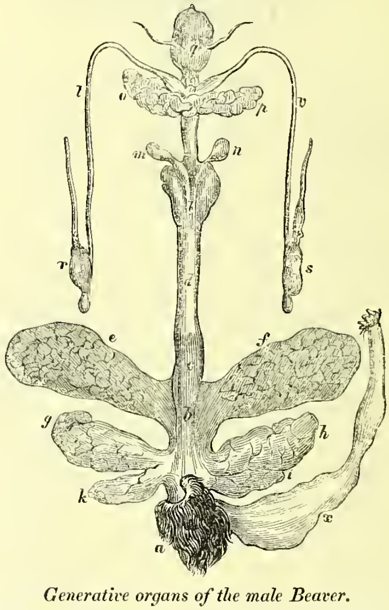
In the squirrel the prostate gland is as long as the muscular portion of the urethra, to which, however, it is only adherent at the two points where its excretory ducts penetrate that canal ; in this animal its shape is oval, flattened above, and bilobed posteriorly.

In the agouti the prostates (*fig.* 282. *e, e*) assume the tubular form, each gland being composed of a common trunk, divided into branches and ramusculi, ending in vascular enlargements.

In the numerous family of rats, the prostates are represented by several packets of ramified tubes, situated around the commencement of the canal of the urethra. Two others are connected with the inferior surface of the vesiculæ seminales : these consist of a principal trunk, which has but few ramifications. These latter organs exist likewise in the lagomys, and may perhaps be considered accessory seminal vesicles.

The Guinea-pig is furnished with numerous ramified and convoluted tubes, connected together by a loose cellular tissue, which occupy the situation of the prostate gland ofother quadrupeds.

Fig. 284.



Generative organs of the male Beaver.

a, opening common to the rectum and the urethral canal; *b*, the prepuce; *c*, glans penis enclosed in the prepuce; *d*, body of the penis; *e, f, g, h, i, k,* preputial glands; *l*, bifurcation of corpus cavernosum forming the bulb; *m, n,* Cowper's glands; *o, p,* vesiculæ seminales; *q*, urinary bladder; *r, s,* testicles; *t, v,* vasa deferentia.

Cowper's glands. — Most of the Rodentia are provided with accessory glands, which, in situation at least, correspond with those called the glands of Cowper in the human subject.

In the male Agouti, these glands are two round, flattened, and very vascular bodies (*fig.* 282. *o*), which open into the bulb of the urethra by separate ducts (*p*). In the Guinea-pig their structure is similar, as like-

wise in the beaver, only they are of much smaller proportionate size.

In the squirrel, Cowper's glands are represented by two large conical bladders twisted upon themselves, the summits of which are evidently of a glandular nature, and are divided internally into numerous small cells. Each of these organs opens by a large orifice into a cul-de-sac, which occupies the interior of the bulb of the urethra, and which is prolonged into a canal, that, becoming gradually narrower, opens into the urethra near the angle formed by the bend of the penis. The walls of the conical bladders, which constitute the substance of these glands, contain muscular fibres, which serve to constrict their cavities. In the Alpine marmot and in the boback, these glands present a similar structure.

In the rats they are of very large size and of a pyriform shape, their substance being enveloped in an aponeurotic sheath.

Penis. — The penis in the Rodentia is differently arranged in different genera. In the Guinea-pig and the agouti, this organ, after running forwards in the ordinary manner as far as the anterior margin of the symphysis pubis, bends back again upon itself beneath the skin of that region towards the anus, so that the opening of the prepuce is situated very little in front of the anal orifice. Muscular fibres, derived from the cremaster muscles, are inserted into the penis near its curvature; and others, derived from the external oblique muscle of the abdomen, are connected with the same point. The former probably contribute to effect the protrusion of the penis from its sheath, whilst the latter draw it back again into its concealment.

In the marmot, the penis, when it arrives in the sub-pubic region, does not bend back again to approximate the anus, but curves directly downwards; in which position it is retained by ligamentous attachments.

In many genera of Rodents, as, for example, in the rats, the voles, the dormice, the jerboa, the hares, and the lagomys, the penis, after issuing from the pelvis, does not run forwards beneath the symphysis of the pubis, but passes directly backwards towards the anus, immediately in front of which the orifice of the prepuce is situated (*fig.* 281. *a*).

In most of the Rodentia the penis contains a bone, imbedded in the substance of the corpus cavernosum. But the most remarkable part of the penis in the order before us, is the glans, which in many species is armed with such a formidable apparatus of spines, saws, and horny spikes, that it must indeed be a rather stimulating instrument of excitement.

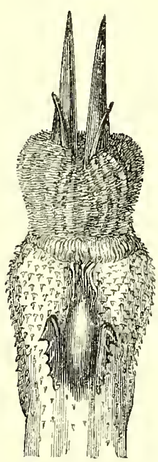
In the Alpine marmot it is conical, and terminated by a sharp point, formed entirely by the extremity of the os penis. On the right of this point is situated the opening of the urethra, and on the left there is a small but deep cul-de-sac.

In the common rat, the extremity of the penis, in its relaxed state, resembles a second prepuce, there being here a wide cavity excavated in the centre of the glands, enclosing a bone, the extremity of which projects beyond it, and is furnished with two small, cartilaginous, lateral appendages. Beneath this is situated the cavity of the urethra. Most of the genera allied to the rats, such as the hamsters, the voles, the dormice, &c., have their penis constructed upon the same plan; but in some the surface of the glans is smooth, whilst in others it is covered with papillæ, or studded with fine hairs.

The glans penis of the beaver is cylindrical in shape, but flattened at its extremity, which is studded with large papillæ, the orifice of the urethra being situated near its centre.

In the Guinea-pig, the penis is supported by a flat and slightly curved bone imbedded in its upper portion, which reaches as far as the extremity of the glans above the canal of the urethra. Behind and below the termination of the urethral canal is a wide pouch, in the bottom of which are lodged two long cartilaginous horns. This pouch, during erection, is everted, so that the horns protrude externally. Two tendons are connected with the bottom of this pouch, which run along the penis inferiorly, and are connected with a thin layer of muscular fibres, derived from the bulb of the urethra and the rami of the corpora cavernosa. These tendons, either by their own elasticity, or by the action of the muscular fibres connected with them, serve to invert the pouch and draw it back again within the glans. The whole surface of the glans is covered with corneous scales, which, with the two horns above mentioned, give it a formidable appearance.

Fig. 285.



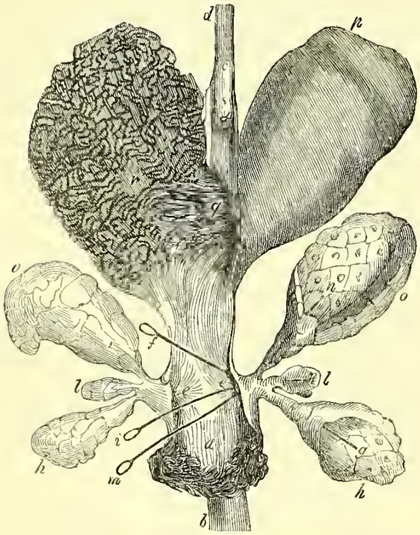
Penis of the spotted Cavy (Cœlogenys subfusca). (Fred. Cuv.)

Yet even this is an innocent weapon when compared with the penis of the agouti and other allied genera, which, besides containing a pouch inclosing strong horny spikes like that of the Guinea-pig, has the whole surface of the glans covered with sharp recurved

spines, and is, moreover, provided on each side with a broad plate of horn, adherent to the glans by its inner border, while all its outer free edge is armed with strong sharp teeth resembling those of a saw (*fig.* 285.); a structure which is additionally remarkable from the circumstance, that in the females of the species thus barbarously armed, the vagina offers no peculiarity in its appearance.

In connection with the male organ of generation may be noticed the preputial glands, which, in some of the Rodentia, are very largely developed. This is more especially the case with the beaver, in which animal they secrete the drug castoreum, once much used in medicine. These glands form

Fig. 286.



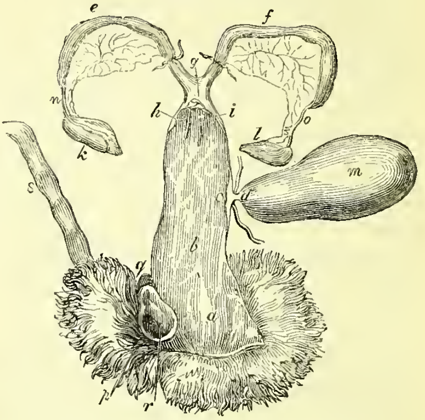
Preputial glands of the Beaver.

a, the prepuce laid open; *c*, attachment of the prepuce around the neck of the penis; *d*, body of penis; *e, e*, opening of the inferior preputial glands; *f, i, m*, stylets passed into the ducts of these glands; *h, l, o*, the glands which on the right side are laid open, to show their internal structure; *p*, superior large glandular sac; *r*, ditto of the opposite side, laid open to show its interior; *q*, opening of these sacs into the preputial canal.

several wide pouches (*fig.* 284. *e, f, g, h, i, k*), situated on each side of the perputial sheath. The structure of these glands is shown in *fig.* 286.; they are arranged in two sets, of which the lower, three in number on each side (*h, l, o*), are found when opened, as represented on the right hand side of the figure, to be hollow, the walls enclosing their central cavity being made up of numerous small glandular masses, that secrete a thick yellowish fluid. The upper set consists of two capacious bags (*p*), which, when opened, are seen to have their lining membrane (*r*) deeply rugose. The secretion of these pouches is of a deep grey colour, and, if possible, more disagreeable.

Female organs of generation. — The ovaria in the female Rodents occupy the same position as in other Mammifera, and are chiefly remarkable on account of the prominence and number of the ova which they contain, giving

Fig. 287.



Generative organs of the female Hare.

a, vulva; *b*, vagina; *c*, orifice of the urethra; *d*, urethra; *e, f*, cornua uteri; *g*, termination of the cornua uteri by two separate orifices (*ora uteri*), into which the probes, *h, i*, have been introduced; *k, l*, the ovaria; *n, o*, Fallopian tubes; *p*, the anus; *q*, anal gland; *r*, cavity situated between the vulva, *a*, and the rectum, *s*.

them a somewhat racemose appearance. The uterus is always deeply divided into two long cornua, and this division is in some cases carried to such an extent that the body of the uterus constitutes but a very insignificant part of this viscus, and is even absolutely wanting, as, for example, in the hare and in the rabbit, in which animals the cornua uteri open separately into the upper part of the vagina, so that the uterus is literally here double, as represented in the appended figure (*fig.* 287.), where two probes (*h, i*) are introduced into the two distinct openings, whereby the two cornua uteri communicate with the vagina.

The vagina presents no peculiarity of structure, even in the females of those genera in which the penis of the male is furnished with the remarkable armature described above.

The mammary glands in the Rodentia vary much in number, some, as the agouti, having as many as from twelve to fourteen nipples; whilst in others, such as the Guinea-pig, there are but four.

(*T. Rymer Jones.*)

ROTIFERA, or ROTATORIA, the name of a class of invertebrate animals which are characterised by the absence of a medullary chord and pulsating vessels; by the possession of a simple tubular alimentary canal; a definite form; a reproduction neither fissiparous nor gemmiparous; the reproductive organs of both sexes in the same individual. Their movements are effected by peculiar rotating organs, and they have no true articulated feet, but mostly a single false foot. The creatures thus constituted are often called wheel-animalcules, from the wheel-like motion

of their ciliated rotatory organs. They were formerly classed together with the polygastric animalcules (POLYGASTRIA), under the common name of Infusoria, on account of their frequent presence with these animals in vegetable infusions. Recent researches, more especially those of Ehrenberg, have shown that the Rotifera possess a much higher and more complicated organisation than the Polygastria; so much so, that in any linear arrangement of the animal kingdom, if the Polygastria were regarded as the lowest beings, several classes might properly intervene between them and the Rotifera. We shall, however, see that there are transitionary forms from the lower to the higher family, sufficiently indicative of their relations and the common circumstances under which they are produced.

For the discovery, and our knowledge of the structure, of the Rotifera, as well as the Polygastria, we are almost entirely indebted to the use of the microscope. Although, generally, the former creatures are much larger than the latter, they were not discovered till after the Polygastria. We are, however, indebted for the first observation of both the one and the other to the sagacity of the same great observer Leeuwenhoek, who, in 1675, first saw the *Vorticella convallaria*, and, in 1702, described the *Rotifer vulgaris*. Previous to this period, no accurate knowledge of creatures so small existed, although the speculations of Plato and the older Greek philosophers, subsequently followed up by Descartes, on the doctrine of living atoms, indicated that the human mind had already felt the possibility of the existence of such conditions of organic matter. Aristotle, too (*Hist. Anim.* v. c. 19.), as Ehrenberg has pointed out, was not unaware of the fact, that coloured water was produced by worms of some kind, which would seem to indicate a knowledge of the existence of some of the forms of Infusoria.

As the discovery of the first Rotifer must be regarded as an era in the history of zoology, we give it in the words of Leeuwenhoek himself:—"On the 25th of August I saw in a leaden gutter, at the fore part of my house, for the length of about five feet, and the breadth of seven inches, a settlement of rain water which appeared of a red colour. . . . I took a drop of this water which I placed before the microscope, and in it I discovered a great number of animalcules. Some of them red, and others of them green. The largest of these viewed through the microscope did not appear bigger than a large grain of sand to the naked eye, the size of the others was gradually less and less: they were for the most part of a round shape; and in the green ones the middle part of their bodies was of a yellowish colour. Their bodies seemed composed of particles of an oval shape; they were also provided with certain short and slender organs, or limbs, which were protruded a little way out of their bodies, by means of which they caused a kind of circular motion and current in the water: when they were at rest, and fixed themselves to the glass, they had the shape of a pear with a short stalk. Upon more carefully examining this stalk, or rather this tail, I found that the extremity was divided into two parts, and by the help of these tails, the animalcules fixed themselves to the glass; the lesser of these appeared to me to be the offspring of the larger ones." This animalcule, which was the *Rotifer vulgaris*, is so accurately described by Leeuwenhoek in the same paper, as to leave little to be added by future describers. Subsequently to the time of Leenwenhoek, who in addition to the *Rotifer vulgaris* discovered the *Melicerta ringens*, a number of species were described by Joblot, Hill, Baker, Rösel, Brady, and others; so that, in 1824, Bory St. Vincent was enabled principally, from the writings of others, to describe eighty species. Up to this time no distinction had been made between the wheel and other animalcules as a class. This separation was effected by Ehrenberg, who has not only examined the structure of these creatures with great care, but has added many new species to the list. In his work on infusory animalcules, he describes 189 species in fifty-five genera and eight families.

The Rotifera, undoubtedly, deserve to be called Infusoria as much as the Polygastria, as they are found very generally with the latter in various kinds of infusions. There are some circumstances, however, under which the Polygastria are developed, in which no Rotifera have yet been found: thus the Polygastria have been found inhabiting water, containing sulphuretted hydrogen and other gaseous constituents, where no Rotiferous animalcules have been found at all. As a general statement, it is true that the Rotifera are the last to appear in infusions; but there are many instances in which Polygastria are developed without the subsequent appearance of Rotifera, and they disappear from infusions sooner than the former. Of the 722 species of Infusoria, described by Ehrenberg, he found that forty-one only were commonly present in the various artificial infusions, which he made in various parts of the world. Of these only three species belonged to the class Rotifera, viz. *Colurus uncinatus*, *Icthydium podura*, and *Lepadella ovalis*. It is the appearance of these animalcules in infusions, which among other things have led to the question of equivocal generation (GENERATION); but whatever ground the low organisation of some of the Polygastria might afford for a belief in this doctrine, the Rotifera have an organisation too high to allow of doubt on this point. The fact of creatures so highly developed being produced in infusions, would create a doubt with regard to the whole theory of equivocal generation, which only positive observation could set aside.

The Rotifera, although classed with the Polygastria as "infusory animalcules," must not be regarded as performing a common function with them in the economy of creation, for not only are there fewer species of Rotifera, but they also exist in much smaller numbers.

Whilst the Polygastria descend in structure to a point where it may be well questioned, whether they partake most of the animal or vegetable character, the Rotifera have always a decided animal character. The Polygastria are even said to perform functions, such as the absorption of carbonic acid and the evolution of oxygen, which would seem to throw doubt on their animality altogether; but no such function can possibly be attributed to the Rotifera. They appear to be distributed as widely on the earth as the Polygastria; and Ehrenberg has recorded their existence in various parts of Europe, Asia, and Africa. They have also been found in America. They inhabit both salt water and fresh, although the species which inhabit the latter are by far the most numerous. Like some of the higher animals, the same species are found inhabiting both salt and fresh water, whilst others are peculiar to brackish water. Although they are capable of pursuing their way in the open water, they are generally found swimming around, or attached to, the leaves and other parts of aquatic plants. In our own country the leaves of Ceratophyllum are found to be a favourite resort of species of *Limnias*, *Mastigocerca*, *Dinocharis*, *Monura*, and others. The floating roots of the various species of Lemna are also the favourite resort of several species, whilst others are found in abundance amongst the fibrilliform fronds of the fresh-water algæ. Some of them even take up their residence in the interior of the cells of plants. Röper first discovered them in the cells of *Sphagnum obtusifolium*. Subsequently Unger described a peculiar movement in certain tubercles which he had observed to be developed upon the stalk of *Vaucheria clavata*. The same phenomenon was witnessed by Professor Morren, of Liege, who, on investigating the subject more closely, found that the movements of the tubercles was due to the presence in their interior of the *Rotifer vulgaris*. Others, again, are found in turfy and bog waters; whilst some, especially the species of *Notommata*, are found parasitic upon other animals.

The Rotifera are more susceptible to the influence of either high or low temperatures than the Polygastria. Ehrenberg observed the latter constantly come to life after the water in which they were contained had been frozen. Species of *Diglena*, *Metopidia*, *Colurus*, and *Lepadella* frequently came to life after they had been frozen for a short time. Other species experimented on, as *Hydatina senta*, *Brachionus urceolaris*, and species of *Salpina*, all died. Although they are easily destroyed by being frozen, some of them will bear a great variety of temperature. Thus the *Philodina roseola*, which we have found in the streams of Yorkshire, has been discovered by Professor Agassiz amongst the red snow of the Alps, where it must have been exposed to a much lower temperature than in the former habitat. Polygastria bear also a higher degree of heat than Rotifera. *Brachionus urceolaris* and *Hydatina senta* were found alive after having been exposed for thirty seconds to a temperature of 104° Fah. Higher temperatures speedily destroyed them.

One of the most remarkable points in the economy of the Rotifera is the power they possess of recovering their vitality after having been apparently perfectly desiccated. This fact was first made known by Leeuwenhoek, who, at the same time that he discovered the existence of the common Rotifer, had an opportunity of observing this remarkable property. In one of his original papers, contributed to the Royal Society of London, he says: —

"In October, 1702, I caused the filth or dirt of the gutters, when there was no water there, and the dirt was quite dry, to be gathered together, and took about a teacupful of the same and put it into a paper upon my desk, since which time I have often taken a little thereof, and poured upon it boiled water, after it had stood till it was cold, to the end that I might obviate any objection that should be made, as if there were living creatures in that water. These animalcula, when the water runs off them or dries away, contract their bodies into a globular or oval figure. After the above-mentioned dry substance had lain near twenty-one months in the paper, I put into a glass tube, of an inch diameter, the remainder of what I had by me, and poured upon it boiled rain water after it was almost cold, and then immediately viewed the smallest parts of it, particularly that which subsided leisurely to the bottom, and observed a great many round particles, most of which were reddish, and they were certainly animalcula; and some hours after I discovered a few that had opened or unfolded their bodies, swimming through the water; and a great many others that had not unfolded themselves, were sunk to the bottom, some of which had holes in their bodies; from whence I concluded that the little creature called the mite had been in the paper, and preyed upon the aforesaid animalcula.

"The next day I saw three particular animalcula swimming through the water, the smallest of which was 100 times smaller than the above said animalcula.

"Now, ought we not to be astonished to find that these small insects can lie twenty-one months dry, and yet live, and as soon as ever they are put into water fall a swimming, or fastening the hinder parts of their bodies to the glass, and then produce the wheels, just as if they had never wanted water. In the month of September I put a great many of the last-mentioned animals into a wide glass tube, which placed themselves on the sides of the glass presently, whereupon I poured the water out, and then observed that several animalcula, to the number of eighteen or nineteen, lay by one another in the space of a coarse sand, all which, when there remained no more water, closed up themselves in a globular figure.

"Some of the bodies of these animalcula were so strongly dried up, that one could see the wrinkles in them, and they were of a

reddish colour; a few others were so transparent, that if you held them up between your eye and the light, you might move your fingers behind them, and see the motion through their bodies.

"After that these animalcula had lain thus dried up a day or two, I invited some gentlemen to come and partake of the agreeable spectacle with me, that is, to see how the said animalcula would divest themselves of their globular figure, and swim about in the water. According to which, after my friends had satisfied their curiosity in viewing the animalcula in their oval or globular form, some of which were so pellucid as if they had been little glass balls, I poured some water into the glass tube, whereupon they presently sunk to the bottom, and then the gentlemen took the said tube into their hands, and viewing it one after another through a microscope, they saw the animalcula, after the space of about half an hour, beginning to open and extend their bodies, and getting clear of the glass to swim about the water, excepting only two of the largest of them, that stayed longer on the sides of the glass before they stretched out their bodies and swam away."

Since the period that Leeuwenhoek made these observations, this subject has been one of great interest to naturalists; and a question has been raised as to the condition of the dried animalcules. Leeuwenhoek seems first to have raised this question, by declaring that complete desiccation must involve the death of an animal, and as it could not come to life after once dead, that the revivified animalcules were not completely desiccated. The experiments of Leeuwenhoek were repeated by other observers, and the same results obtained. Needham not only saw it in the Rotifers, but also in the Vibrio of blighted wheat. His opinion was, that the desiccation was quite complete. Needham's experiments were repeated by Baker, who also came to the same conclusion. These observers were followed by Spallanzani, who, in a most elaborate series of investigations, confirmed the conclusions at which Needham and Baker had arrived. He, however, points out the fact, that the revivification of the animalcules was much more constant when they were dried with sand than when dried on a smooth surface. He found also that animalcules when in this desiccated state would bear a much greater heat, as well as a much more intense degree of cold, than when in an active state. Animalcules that, whilst living, would not bear a higher temperatare than 100° Fahr., when dried were resuscitated after having been exposed to a temperature of 144° Fahr. They also recovered after being exposed to a degree of cold 24° cent. below zero. Although numerous facts of the same kind were recorded by subsequent observers, the accuracy of these observations have been doubted by several eminent naturalists, at the head of whom stands Bory St. Vincent, who, in the article *Rotifères,* in the Dictionnaire Classique d'Histoire Naturelle, says, that the desiccated animals have not been resuscitated at all, but that they are developed from eggs, in the same way as the *Daphnia* and other minute entomostracous crustacea are developed after the first shower of rain which falls on the soil in which their ova are contained. The correctness of these observations can now hardly be doubted; and since the time that Bory St. Vincent wrote, a great number of observers of undoubted accuracy, have repeated the experiments of Spallanzani and others, and have arrived at the same conclusions. Doyère, a French naturalist, published a very extended series of investigations on this subject, in the Annales des Sciences Naturelles for 1842, in which various species of animalcules were perfectly desiccated and resuscitated under circumstances which would entirely prevent the supposition of a development such as was suggested by Bory St. Vincent. Experiments of the same kind have been performed by observers in our own country. Dr. Carpenter says, "In the summer of 1835, I placed a drop of water containing a dozen specimens of the *Rotifer vulgaris* on a slip of glass, and allowed the water to dry up, which it did speedily, the weather being hot. On the next day I examined the glass under the microscope, and observed the remains of the animals coiled up into circles; a form which they not unfrequently assume when alive, but so perfectly dry that they would have splintered in pieces if touched with the point of a needle, as I had observed before in similar experiments. I covered them with another drop of water, and in a few minutes ten of them had revived, and these speedily began to execute all their regular movements with activity and energy. After they had remained alive for a few hours, I again allowed the water which covered them to dry up, and I reviewed it on the following day with the same result. This process I repeated six times; on each occasion one or two of the animals did not recover, but two survived to the last, and with these I should have experimented again had I not accidentally lost them."

Professor Owen in his Lectures, after alluding to the experiments of Professor Schulze on this subject, says, "I myself witnessed at Freiburg, in 1838, the revival of an *Arctiscon,* which had been preserved in dry sand by the professor upwards of four years." We must, however, quote one great authority against the view that a perfect desiccation of the resuscitated animals has ever taken place, and that is Professor Ehrenberg himself. He does not go so far as Bory St. Vincent, but regards the desiccation spoken of as an assumption, and supposes that the rotiferous and other animalcules which are revivified have the power of living in both water and air; although they do not perform their functions so actively in the latter, yet that they still perform them. He says that he has seen the stomachs of Rotifera filled with granules of a conferva which was growing in the sand in which they were supposed to have been desiccated. Although we feel that the opinions of

Ehrenberg on the subject of animalcules are entitled to great respect, we think that he has not investigated this subject with the candour that would entitle his conclusions to confidence. There is no *a priori* evidence why a perfect desiccation and suspension of the functions of life should not take place. This is the natural condition of the embryo of the seeds of many plants, which, after hundreds of years, when placed in proper circumstances, will exhibit all the functions of vegetable life. Amongst the highest forms of animals we often witness a suspension of the functions under special external circumstances, which, although not amounting to the extent found amongst the Infusoria, would yet prepare us to admit a far more intense degree of the same phenomenon amongst those beings in which animality was less decided, and the vegetative functions more predominant. There is no necessity to regard the condition of desiccation in which those animals may be placed as one of death. The conditions of the existence of the vitality of the animal, whatever they may be, are undoubtedly secured in this state, and the conditions of the *activity* of this vitality are alone withdrawn.

Although many of the species of Polygastria are as large as the Rotifera, the structure of the latter is much more easily discernible, on account of the transparency of the lorica, or shield, in which they are enclosed, and the distinctness of their individual organs. The external covering, though always clear like crystal, has varying degrees of density, in some instances forming a horny kind of case, insusceptible of movement, and, in others, a skin susceptible of transverse corrugations. Into this dense external membrane the animal is capable of drawing in its tail and rotatory organs; hence this class of animals has been called Systolides. In none of the species does there appear to be a deposit of earthy salts, either in the skin or other parts of the body.* This will account for the fact, that few or none of the Rotifera have been found in a fossilised state. Those forms alone of the Polygastria have been discovered in the chalk and subsequent formations, which, in their living state, possess a siliceous or calcareous skeleton.

In the classification of the Rotifera we shall follow Ehrenberg, as no separate arrangement of these creatures existed previous to his profound investigation of their structure; and although other attempts have been made, since the appearance of his work, on the Infusoria, none of them seem better adapted for the purposes of further inquiry. At the same time we would, with the utmost diffidence, express our doubts as to the correctness of much of the terminology employed by Ehrenberg, implying, as it frequently does, views of the structure and functions of the parts of these animals which the facts themselves, so remarkably correctly observed, do not always seem to warrant. The following is a table of the eight families of Rotifera according to Ehrenberg: —

A single, continuous, ciliated wheel. (MONOTROCHA.)	Margins of the wheels entire. (HOLOTROCHA.)	Skin soft, or naked.	*Icthydina.*
		Skin hard or loricated.	*Œcistina.*
	Margins of the wheels crenated. (SCHIZOTROCHA.)	Naked.	*Megalotrochæa.*
		Loricated.	*Floscularia.*
A compound, or divided, ciliated wheel. (SOROTROCHA.)	Many-parted wheels. (POLYTROCHA.)	Naked.	*Hydatinæa.*
		Loricated.	*Euchlanidota.*
	Two-parted wheels. (ZYGOTROCHA.)	Naked.	*Philodinæa.*
		Loricated.	*Brachionæa.*

It will at once be seen that this is an exceedingly artificial arrangement; for although the rotatory organs are the most striking external character of the Rotifera, the function they perform does not seem to be of that fundamental importance in the economy of the animal, so that a change in their form would be attended with corresponding changes in their general structure. In fact, in this arrangement, forms are separated which are nearly related by the affinities of more important organs. In the next place, the families are arranged according as they are naked (panzerlose), or loricated (gepanzerte). The condition of the integument here employed as a means of classification, cannot be regarded as absolute; and there are species which it would be difficult to refer to either group. Some of the species secrete around them an external tube, in which they dwell, as Stephanoceros (*fig.* 292.) and others, which is an entirely different thing from the hardened integument called by Ehrenberg the lorica, or shield, and yet these are classed as a loricated family. It is, however, but due to Ehrenberg to state that he is not unaware of the defects of this arrangement, and that he has pointed out that both the structure of the alimentary canal, and even the teeth and jaws, would afford characters by which the species might be arranged. Dujardin, in a recent work on the Infusoria, proposes the four following families: —

1. Rotifers having the posterior part of their bodies *fixed*. Examples: *Floscularia*, *Stephanoceros*.

2. Rotifers having but one means of locomotion, that of the vibratile cilia, and which are consequently always *swimmers*. Examples: *Ptygina*, *Lacumolaria*, *Melicerta*.

3. Rotifers which have two modes of locomotion: one creeping like the leech, the other swimming as the last. This family includes the largest number of genera, as *Brachionus*, *Dinocharis*, *Pterodina*, *Salpina*, *Lepadella*, *Euchlanis*, &c.

* Ehrenberg states that the remains of some Rotifera having been chemically examined; they were found to contain phosphate of lime, which he supposes was deposited in their jaws and teeth.

4. Rotifers without vibratile cilia, but which are supplied with nails, by means of which they walk. Examples: *Hydatina, Notommata, Furcularia, &c.*

Dujardin, in his work, also objects to the characters on which Ehrenberg has constituted the various genera belonging to his eight families, these genera being principally determined by the presence or absence of little red spots, which Ehrenberg designates as eyes. (*Fig.* 292. *a*; *fig.* 303. *a*; *fig.* 296. *a*; *fig.* 294. *a*; *fig.* 298. *a*; *fig.* 299. *b.*)

The following is a description of the families adopted by Ehrenberg:—

Family 1.—Icthydina. *Character.* Naked Rotifers, with a single continuous rotatory organ, not lobed at the margin.

In the genera *Ptygura* and *Glenophora*, the rotatory organ is circular, and serves as a means of locomotion. In *Chætonotus* and *Icthydium* it is elongated, elliptical, band-like, and seated on the ventral surface. *Chætonotus* and *Icthydium* possess a furcated foot, *Ptygura* and *Glenophora* a simple one. *Icthydium* and *Chætonotus* have a simple conical intestine, with a long thin œsophagus without teeth (?) *Glenophora*, a short œsophagus with two teeth; *Ptygura*, a constricted stomach with three teeth (*fig.* 288.). Pancreatic glands are only seen in *Chætonotus* and Ptygura. Cæcum, gall-ducts, and male sexual organs not observed. In two genera, the female sexual system consists of an ovarium with a few large ova. The evidence of the existence of a nervous system is seen in the two large red frontal eyes of Glenophora. Chætonotus has a hairy back.

Analysis of the genera:—

Eyes absent.	No hair.	A single foot.	*Ptygura.*
		A furcated foot.	*Icthydium.*
	Hairy.		*Chætonotus.*
Two eyes.			*Glenophora.*

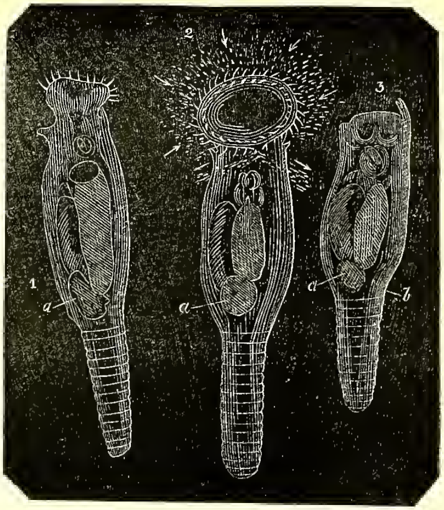
These genera embrace six species, some of which have been known to microscopic observers under various names, from a very early period. *Icthydium podura* was described by Joblot, as poisson à la tête tréflée, in 1718. The *Chætonotus larus* was described by Müller in 1776 as *Trichoda acarus.*

This family embraces some of the simplest forms of the Rotifera. It may perhaps be doubted as to whether this class at all is the place for the genus *Chætonotus.* They have no distinct rotatory organ, and their bodies covered with cilia, place them in very close alliance with some forms of the Polygastria, especially the Euplota, from which they are distinguished by their symmetry, and distinctly furcated tail. Dujardin places *Chætonotus* amongst his symmetrical Infusoria, which do not include the Rotifera or Systolides.

Family 2.—Œcistina. *Character.* Rotiferous animals, with a single rotatory organ entire at the margin, enclosed in a shield.

The organs of motion consist of internal muscles and an entire foot or tail. The organs of nutrition are an apparatus with rows

Fig. 288.



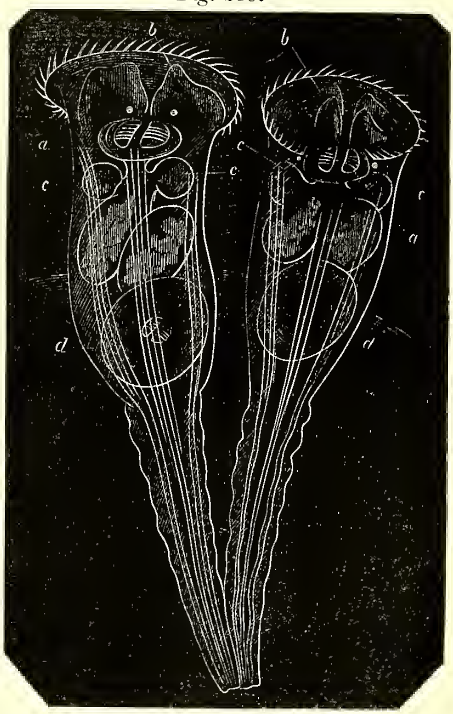
Ptygura melicerta. (*After Ehrenberg.*)

1, partially expanded; 2, completely expanded, the cilia in action causing currents indicated by the arrows; 3, contracted.

a, a, a, contractile vesicle; *b,* situation of the anal orifice.

of teeth for chewing (*fig.* 289. *a, a*), two pancreatic glands. Ova and ovaria have been

Fig. 289.



Conochilus volvox. (*After Ehrenberg.*)

a, a, jaws and teeth; *b, b,* papillæ; *c, c, c, c,* glands; *d, d,* ovarium.

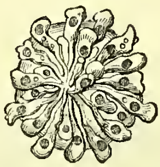
observed in the two forms of which the family consists. Vessels, two filiform tremulous organs (called by Ehrenberg "gills"); nervous

fibres, with ganglia, are seen in *Conochilus*, and two red eyes are seen in both genera.

Lorica, or shield.	Confined to an individual.	*Œcistes.*
	Common to many.	*Conochilus.*

In the less circular rotatory organ than in *Ptygura* we see the tendency in these animals to the more compound forms of that organ. The lorica, in this family, is not homologous with this organ in many of the other loricated species; but a case formed by a secretion from the surface of the body of the animal, as is seen in some Annelides, and occasionally in the aquatic larvæ of insects. The social habit of *Conochilus* is very remarkable in this group, as many as forty individuals being frequently found together, attached by their tails, and the consequence of the action of their rotatory organs is a circular movement of the whole mass (*fig.* 290.). This habit is not confined to *Conochilus* amongst the Rotifera; but it is interesting as connecting this class in habit with the compound Polygastria on the one side, and the Cirripedia and compound Ascidia on the other.

Fig. 290.



The animals of Conochilus volvox, half contracted, forming a circle. (After Ehrenberg.)

Family 3.—Megalotrochœa. *Character.* Monotrochous rotatory animals, with the margin of the rotatory organ incised or flexuous, not inclosed in a shield.

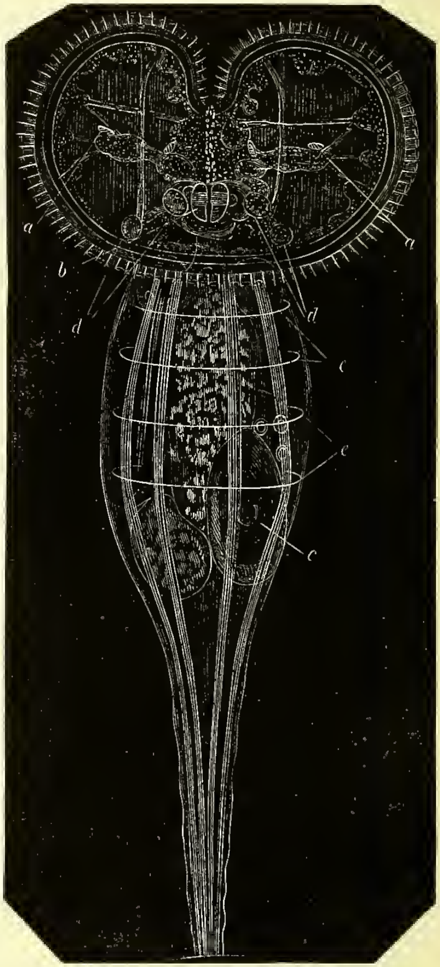
The flexuous extended rotatory organ is used for locomotion, swimming, and the supply of nutriment. Muscular bands are evident in the interior, by which the form of the body is changed. In *Megalotrocha*, the alimentary canal is supplied with a stomach, two cæca, jaws with a double row of teeth, and two pancreatic glands. In the other two species there is a single canal, without stomach or cæca. *Microcodon* has jaws with two teeth. *Cyphonautes* is toothless. The reproductive organs consist of an ovarium. The ova in *Megalotrocha* are attached to the parent by a thread. Vessels, and tremulous gill-like organs, are observed in *Megalotrocha.* The organs of the senses are in two genera — the red eyes. *Megalotrocha* exhibits radiated nervous masses, and above these four dark glandular bodies in the neighbourhood of the mouth. These have been erroneously regarded as eyes (*fig.* 291.).

Analysis of genera.

Eyeless.		*Cyphonautes.*
With eyes.	One eye.	*Microcodon.*
	Two eyes.	*Megalotrocha.*

Of these three genera, *Megalotrocha* is the only one that is well known, or that appears to answer to the description of the family. *Cyphonautes* is a marine animal, of which Ehrenberg has seen but two specimens. *Microcodon* has also doubtful characters. *Megalotrocha*, of which there is only one species, *M. albo-flavicans*, has often been described by the older observers.

Fig. 291.



Megalotrocha flavicans. (*After Ehrenberg.*)

a, a, nervous ganglia; *b,* jaws; *c,* ovum; *d, d,* bodies whose functions are unknown; *e, e, e, e,* transverse vessels.

Family 4. — Flosculařia. *Character.* Monotrochous loricated Rotifers, with a rotatory organ, with sinuous lobed or multifid margins.

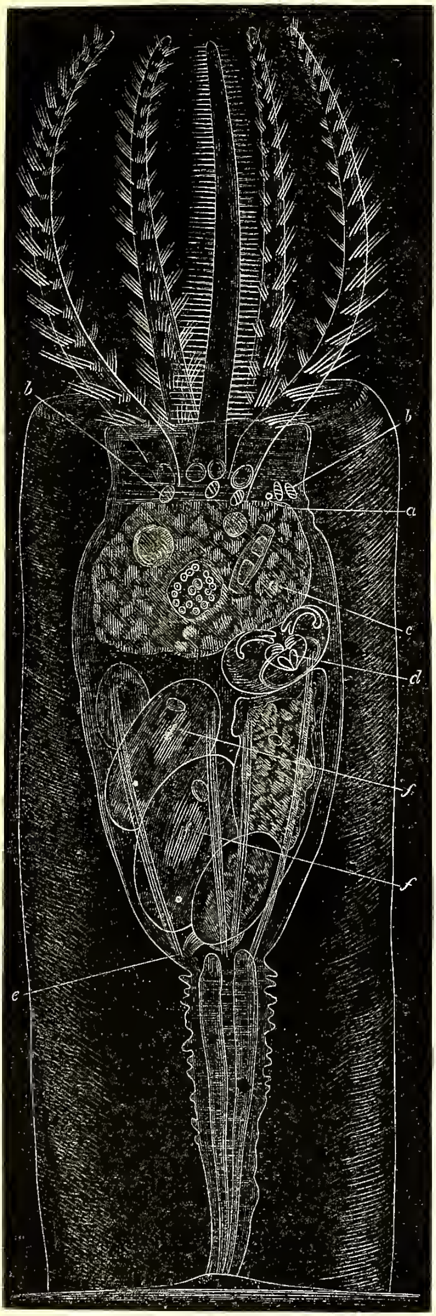
The rotatory organ is divided more or less deeply into two, four, five, or six divisions. In the last case they may be almost said to be compound. The alimentary canal generally exhibits a stomach, and is supplied with jaws and teeth. *Floscularia* has no stomach. *Lacinularia* has two cæca. Semilunate pancreatic glands are seen in all the species. A short ovarium, producing a few ova at a time,

is found near the foot in all the genera. Male organs, as glands, exist in *Lacinularia* and *Melicerta*, perhaps also in *Floscularia* and *Stephanoceros*. Vessels are seen in *Lacinularia*. Tremulous gill-like organs in *Stephanoceros* and *Lacinularia*. Eyes are seen in all except *Tubicolaria*. Nerve-like ganglia may be found in *Lacinularia*, *Limnias*, and *Melicerta*. Two pairs of muscles contract the body posteriorly (*fig* 5.).

Analysis of the genera.

Eyes not present.			*Tubicolaria.*
One eye.			*Stephanoceros.*
Two eyes (when young).	Wheels 2-parted.	Separate.	*Limnias.*
		Segregate.	*Lacinularia.*
	Wheels 4-parted.		*Melicerta.*
	Wheels 5-or 6-parted.		*Floscularia.*

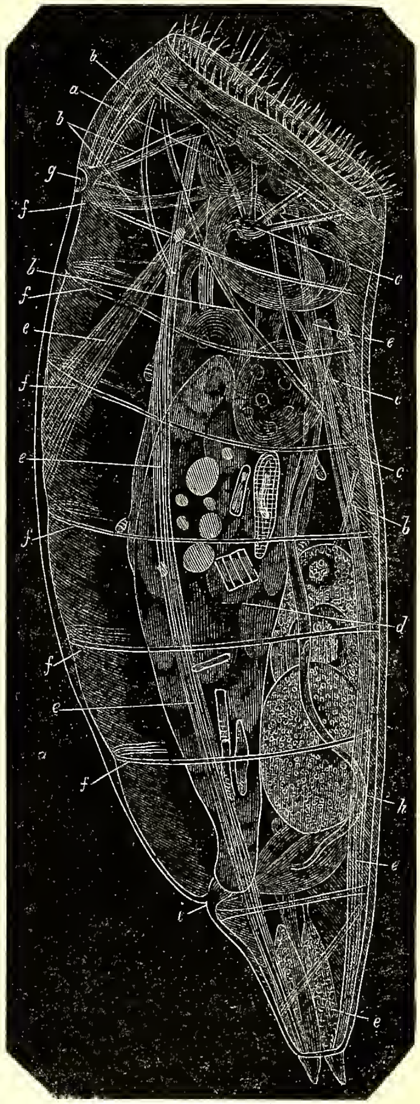
Fig. 292.



Stephanoceros Eichornii. (*After Ehrenberg.*)

a, single eye; *b*, *b*, nervous ganglia; *c*, crop, containing a navicula and other infusory animalcules; *d*, jaws; *e*, anal orifice; *f*, *f*, ova.

Fig. 293.



Hydatina senta. (*After Ehrenberg.*)

a, brain; *b*, nervous cords; *c*, ganglia; *d*, alimentary canal, containing infusory animalcules; *e*, *e*, *e*, *e*, muscular fibres; *f*, *f*, *f*, *f*, transverse vessels; *g*, respiratory orifice; *h*, seminal tubes; *i*, anal orifice.

Although, at first sight, this might appear a very natural group, a little examination of their so-called rotatory organs will suggest the propriety of separating from the rest the genera *Floscularia* and *Stephanoceros*. The organs which are called rotatory in those genera are evidently, as Dujardin has pointed out, more like to the bristles or setæ of the lorica of other species, than to the true rotatory organs. The cilia, as they are called, of *Floscularia*, do not move at all. The bristle-like organs of Stephanoceros are covered with cilia, which appear to be vibratile. The loricæ of these animals also consist not of the integument rendered horny, but of a case secreted from the outside of the body of the animal. The animal has the power of retiring into this case, and in *Stephanoceros* this habit, combined with its structure, give to it a strong resemblance to some of the Cilio-brachiate Bryozoa. This external resemblance is so great, that many of the earlier observers referred it to the Polypifera. Oken referred it to the hydroid polyps, and placed it between *Hydra* and *Tubularia*. Goldfuss referred it to a position in the same class between *Coryna* and *Cristatella*.

In the genus *Lacinularia*, the same tendency to association exists, as is found in *Conochilus*.

The genera *Floscularia* and *Stephanoceros* constitute the first family of Dujardin. The remaining genera, previously noticed in this and the other families, are referred to his second family.

Family 5.—Hydatinæa. *Character*. Naked Rotifers, with a many-parted rotatory organ.

All the species of this family agree in the divided condition of their wheels, which do not consist of a circular or semi-circular row of cilia, but of several distinct rows or circles of such cilia, which are distinctly separated from each other. All the three forms, except *Polyarthra*, have an elongated pincer-like process, proceeding from the abdomen, which resembles a tail, but is no proper continuation of the dorsal integument. In many species, a muscular apparatus is visible, by which the form of the body is changed. The nutritive organs in all cases are very obvious. It is mostly a simple conical intestine, which, in the great proportion of species, is without the constriction, which forms a kind of stomach (*fig.* 293. *d*). *Triarthra longiseta* (*fig.* 297.) is, however, an exception, and exhibits a stomach formed by the constriction of the alimentary canal; whilst *Notommata myrmeleo* (*fig.* 303. *c*) with some other species have a kind of gastric enlargement, terminated by a narrow anal orifice. The commencement of the alimentary canal, with one or two exceptions, in all the genera, is supplied with jaws and teeth. Pancreatic glands are constantly present. The reproductive system is hermaphrodite. The ovarium (*fig.* 303. *i*) is elongated; the eggs few. The male organs consist of two filiform elongated glands (*fig.* 303. *g*), and two contractile vesicles. The ova appear under two forms, one smooth and soft, the other hard and spinous. *Notommata brachionus*, and the genera *Polyarthra* and *Triarthra*, bear their ova, like the Crustacea, attached to their sides. In several of the genera a vascular system has been observed (*fig.* 293. *f, f, f, f*), in the form of transverse and longitudinal vessels, the latter supplied with the tremulous organs called gills (*fig.* 303. *f, f*). With this system, a kind of tap, or simple opening, in the neck (*fig.* 293. *g*) is connected. In fifteen of the genera, the two eyes, with their accompanying nervous ganglia (*fig.* 293. *c*), indicate the existence of a sensationary system. In Hydatina and other genera, nervous ganglia are seen in other parts of the body.

Analysis of the genera.

Eyeless.	No teeth.				*Enteroplea.*
	With teeth.	Teeth many.			*Hydatina.*
		Teeth single.			*Pleurotrocha.*
With eyes.	One eye.	Eye frontal.			*Furcularia.*
		Eye in neck.	Foot styliform.		*Monocerca.*
			Foot furcated, cilia frontal.	With style.	*Synchæta.*
				With hooks.	*Scaridium.*
				Without either.	*Notommata.*
			No foot, divided fins.		*Polyarthra.*
	Two eyes.	Eyes frontal.	A furcate foot.		*Diglena.*
			Styliform foot.	Bearded.	*Triarthra.*
				Not bearded.	*Rattulus.*
		Eyes in neck.	Foot furcate.		*Distemma.*
	Three eyes.	Eyes sessile.	In neck.		*Triophthalmus.*
			Two frontal, one in neck.		*Eosphora.*
		Two frontal pediculated, one in neck sessile.			*Otoglena.*
	Eyes more than three.	In single heaps.			*Cycloglena.*
		In two heaps.			*Theorus.*

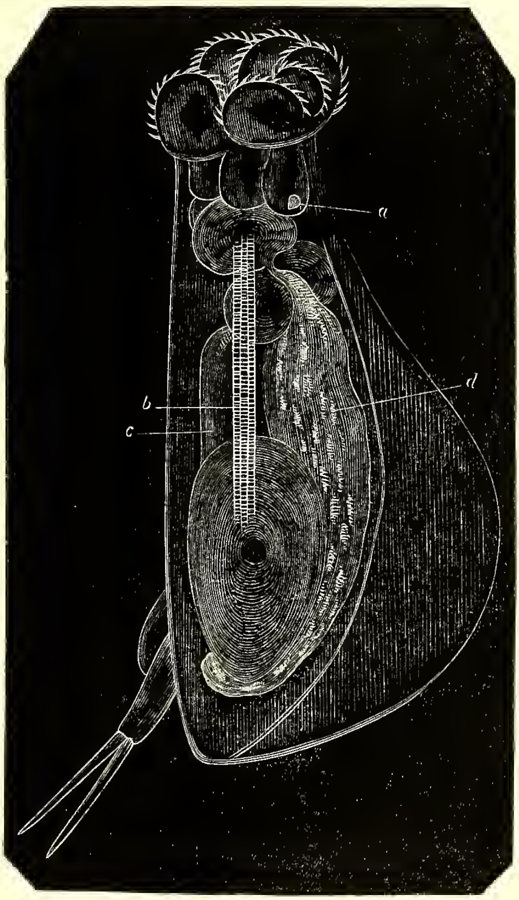
This family contains a larger number of species than any of the others. They are very generally diffused; and Ehrenberg, in his microscopic labours, in many parts of the

world, observed them in the north of Africa and the north of Asia; they are commonly distributed throughout Europe. The localities they inhabit are very various, some are found in fresh water, other in salt. They are fond of confervæ, and may be easily found nestling among these plants. They sometimes are in great numbers, so that they discolour the waters in which they exist. The species of *Triarthra* give a milky opaqueness to the water in which they are found. The species of *Polyarthra* are interesting on account of the finlike organs which are developed at their sides, and by which they are able to move about. Several of the *Notommata* are parasitic on other animals, and thus approach in habit some of the higher epizoa. The elongated setæ or bristles of the species of Triarthra are also worthy of notice (*fig.* 297.).

Family 6. — EUCHLANIDOTA. *Character.* Loricated Rotifers, with a many-parted rotatory organ.

All the species of this family are clothed with a lorica, which resembles the exoskeleton of tortoises or crabs. Many of the species are remarkable for the appendages of the shield, as *setæ* in *Euchlanis* and *Stephanops*, hooks (*uncini*) in *Colurus*, horns (*cornicula*) in *Dinocharis*, spurs or respiratory tubes (*calcar sipho*) in *Euchlanis* (*fig.* 294.) and *Salpina*, a helmet (*cucullus*), in *Stephanops*. Most of the species have a furcated foot, some few of them have styliform feet. The interior of these animals is not so well observed as in families where the shield is of a less dense character. A muscular system, consisting of both longitudinal and transverse fibres, and muscles to move the foot, can be seen in most species. The nutritive organs consist of a muscular œsophageal head, furnished with two jaws bearing teeth. The œsophagus is mostly a short tube. In eight genera the alimentary canal assumes a conical form, in the remainder it is constricted into a gastric organ. Two round or egg-shaped intestinal glands are present in all the species. The anal orifice is situated at the back of the basis of the foot (*fig.* 302. *a*). An ovarium with small ova, in four genera, *Euchlanis*, *Monostyla*, *Stephanops*, and *Squamella*, are seen, in the form of

Fig. 294.



Euchlanis triquetra.

a, single eye; *b*, band of muscles with transverse striæ; *c*, ovarium; *d*, alimentary canal.

two strap-shaped sexual glands and contractile vesicles. Traces of a vascular system are seen only in a few species. The sensationary system is indicated by the presence of eyes, which are visible in ten genera and thirty-three species.

Analysis of the genera.

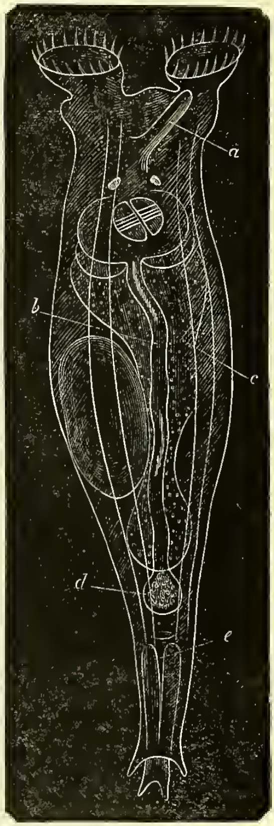
Eyes absent.		Foot furcate.			*Lepadella.*
Eyes present.	One eye in neck.	Styliform foot.	Depressed shield.		*Monostyla.*
			Prismatic shield.		*Mastigocerca.*
		Furcated foot.	Shield gaping beneath.		*Euchlanis.*
			Shield closed beneath.	Shield horned.	*Salpina.*
				Shield without horns.	*Dinocharis.*
	Two eyes frontal.	Styliform foot.			*Monura.*
		Furcated foot.	Shield somewhat compressed or prismatic.		*Colurus.*
			Shield depressed or cylindrical.	Hooded.	*Stephanops.*
				Not hooded.	*Metopidia.*
	Four eyes.	Furcated foot.			*Squamella.*

In this as in the preceding family, there can be little doubt that the artificial character, the number and position of the so-called eyes, on which the genera are founded, separates species which are united by much more important characters. Thus Dujardin remarks, that the genera *Lepadella*, *Metopidia*, *Stephanops*, and *Squamella* are separated only by characters which vary according to the nutrition of the animal and the time of the year. The same remark will apply to many of the genera of the preceding family Hydatinæa. The species of this family are found in both salt and fresh waters, and have a wide distribution over the surface of the earth. The genus Lepadella is developed sometimes in stagnant water in such quantities as to give it a milky appearance.

Family 7. — PHILODINÆA. *Character.* Naked Rotifers with two rotatory organs.

The body of these animals is mostly of a tenuiform, cylindrical, or spindle-shape, with false articulations, by which, through its muscles, the animal is enabled to withdraw the parts of its body one within another, like the tube of a telescope. The double rotatory organ, so evident in Rotifers (*fig.* 301.), is seen in all the species. In every species there is a furcated foot. In the genera *Callidina*, *Rotifer*, *Actinurus*, and *Philodina*, appendicular hooks are found on the false articulations (*fig.* 295.). A muscular system is seen in *Callidina*, *Actinurus*, *Rotifer*, and *Philodina*. Three of the genera have two jaws with two teeth, and two jaws with a row of teeth. A filiform intestine, with a vesicular enlargement at the end, is seen in four of the principal genera. Intestinal glands are seen in four genera. The reproductive system is hermaphrodite in four genera, with an ovarium and male sexual glands, and contractile vesicles. The last are only seen in *Rotifer* and *Philodina*. These two genera and *Actinurus* sometimes produce living young. Traces of a vascular system in the transverse vessels of *Rotifer* and *Philodina*, and also in the respiratory tube or opening of these genera, and of *Actinurus* and *Monolabis*, are seen. Nervous masses are found under the eyes.

Fig. 295.



Philodina roseola. (*After Ehrenberg.*)

a, respiratory tube; *b*, alimentary canal; *c*, cellular mass; *d*, terminal intestinal pouch; *e*, anal orifice.

Analysis of the genera.

Eyes absent.	With proboscis, and appendicular processes on foot.			*Callidina.*
	No proboscis or processes.	Wheels pedunculated.		*Hydrias.*
		Wheels sessile.		*Typhlina.*
Eyes present.	Two frontal eyes.	Foot with processes.	Two toes.	*Rotifer.*
			Three toes.	*Actinurus.*
		Foot without processes.	Two toes.	*Monolabis.*
	Two cervical eyes.			*Philodina.*

This family, which includes the true Rotifers of Dujardin, embraces some of the least known, as also the most common, animals of the class. The genera *Hydrias* and *Typhlina* were found during the travels of Ehrenberg in Asia. *Callidina* and *Monolabis* have been found by Ehrenberg at Berlin only. The *Rotifer vulgaris* was the first wheel-animalcule ever seen, and is certainly the most common of the whole class. It was described with great accuracy by Leeuwenhoek in in his early papers on its discovery. It is this animal which has also been most frequently the subject of the desiccating experiments to which we have alluded. *Actinurus Neptunius* was known to the earlier observers of these creatures as the wheel-animalcule with the long foot, on account of the extension of its foot or tail. The *Philodina*, though not an unfrequent genus, was first described by Ehrenberg in 1838. The articulated character of the integument in the species of this family, give them a habit different from the rest of the group: by means of their probiscoid mouth and prehensile tail, they can successively grasp the object on which they are placed, and are thus enabled to crawl in the same way as the leech and other Annulosa. The affinity between the Rotiferæ proper and the *Arctiscon* and whole family of Tardigrades, which are not admitted as Infusoria by Ehrenberg, has been pointed out by Doyere; and there can be little doubt that we have, through this group, a transition from the Rotiferæ to the Annelida.

The *Rotifer vulgaris* is found very commonly in the ponds and ditches of England, where it attaches itself to the Confervæ, the various species of Lemna, and the Ceratophyllum, which are so abundant in these places. M. Morren, of Liege, has recently pointed out a curious habitat for this animal. Rœper, many years ago, observed that this animalcule sometimes penetrated the cells of *Sphagnum*, and even lived in those parts of the plant which were not immersed in water. Unger described, in 1828, some vesicles in the structure of *Vaucheria clavata*, which had the power of moving about spontaneously, and which he discovered were produced by an animalcule in their interior. The subsequent researches of Morren showed that this animalcule was truly the *Rotifer vulgaris*. It seems to prefer such a situation to its liberty, for Morren says, "One day I opened a protuberance gently; I waited to see the Rotifer spring out and enjoy the liberty so dear to all creatures, even to imprisoned animals; but no, he preferred to bury himself in his prison, descending into the tubes of the plant, and to nestle himself in the middle of a mass of green matter, rather than swim about freely in the neighbourhood of his dwelling."

The species of *Philodina* are beautiful animalcules. *P. roseola* has a rose colour of its whole body; and the ova, when deposited, have a reddish colour. The ova of this animalcule are deposited in little heaps, which the parent attends to, and even remains with the young ones after they are hatched, which Ehrenberg attributes to a kind of social instinct. Professor Agassiz found this creature amongst the animalcules which contribute to the colour of the red snow. It was at one time supposed that this colour was due to a species of Alga, the *Protococcus nivalis*. Mr. Shuttleworth, of Berne, was the first to announce that he had found, in addition to the cells of a plant, several species of Polygastria, belonging probably to the genus *Astasia*. Subsequently to this announcement, Professor Agassiz discovered the presence of this animalcule in the same situation. The author of this article has found *Philodina roseola* in company with a red animalcule, apparently a species of *Astasia*, in waters slightly impregnated with sulphuretted hydrogen. Ehrenberg says this animal sometimes occurs entirely colourless, so that its colour may depend on its food.

Family 8. — Brachionæa. *Character.* Loricated Rotifers, with a double rotatory organ.

The external covering of these animals is a testula, such as is possessed by the tortoises, not a scutellum, as found in the Crustacea. The motory system consists partly of external organs, and partly of internal muscles. The rotatory apparatus is often apparently composed of five parts — three in the middle and one on each side. The latter only can be regarded as the true rotatory organs; the middle portions are only ciliated frontal processes. In the genus *Synchæta* there are two setæ in the rotatory organs, which are also possessed by the Brachionæa. *Noteus* and *Brachionus* have a furcate foot, *Anuræa* is footless, and *Pterodina* has a kind of sucker in its place. The nutritive organs are very similar to those of the Hydatinæa and Euchlanidota. Intestinal glands have been observed in all the species. The reproductive organs consist of an ovarium, with a few large eggs, which are not hatched internally, but, with the exception of *Pterodina*, are externally attached to the parent after expulsion. The male organs consist of glands and contractile vesi-

cles. The vascular system is composed of tremulous gill-like organs, and a respiratory spur or tube in some species. *Noteus* has no eyes, but a large cerebral ganglion; the other genera have eyes.

Analysis of the genera.

Eyeless, with furcate foot.			*Noteus.*
With eyes.	One in neck.	Without foot.	*Anuræa.*
		Foot furcated.	*Brachionus.*
	Two frontal eyes.	Styliform foot.	*Pterodina.*

With the exception of *Noteus*, the genera of this family were known to the older observers. Three species of Anuræa were described by Müller in 1776, and Joblot discovered the *Brachionus pala* (*fig.* 296.) in 1716. The *Pterodina patina* was described by *Eichorn* in 1775. The genus *Brachionus* is, of all the Rotifers, the most remarkable for the density of its lorica. The thickness of this organ prevents their internal structure from being so plainly observed as that of many other genera. The species of *Brachionus* often occur in so large quantities that they render the water turbid in which they exist.

Doyere has constructed a family which he calls Tardigrades, and which are most properly included in the class of Rotifera. The animals of this family have an elongated body, contractile like that of the Rotifer, with four pairs of short legs, each bearing two pairs of small claws. The alimentary canal is narrow, prolonged into a siphon at its anterior extremity, with an internal maxillary apparatus, moveable, and consisting of a muscular bulb traversed by a straight canal, furnished with horny articulated pieces. Until this family was investigated by Doyere, it was supposed to consist of but one species, the Water-bear (Wasser-bär) of Eichorn; but under the name of *Macrobiotus*, *Arctiscon*, and other names, which were supposed to be synonymous, it appears that several animals were confounded, for which Doyere proposes the generic terms *Emydia*, *Milnesia*, and *Macrobiotus*. These animals are found in the same localities as the common Rotifer, and like it possess the

Fig. 296.

Brachionus pala. (*After Ehrenberg.*)

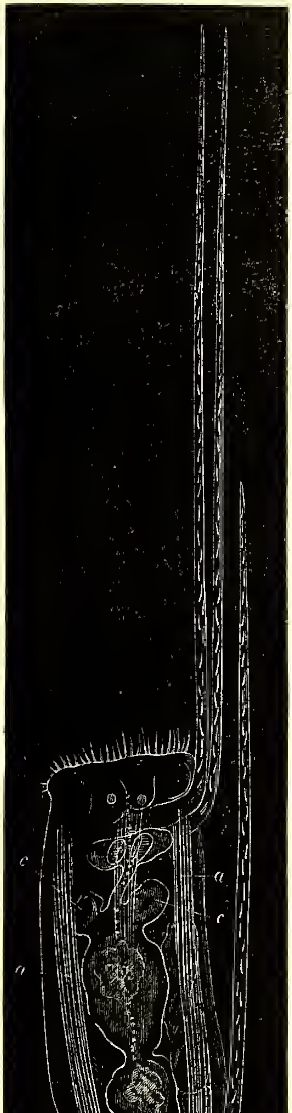
a, eye; *b*, jaws; *c*, ovary; *d*, *d*, ova; *e*, contractile vesicle; *f*, ova attached; *g*, *g*, *g*, teeth of shell; *h*, *h*, intestinal glands; *i*, constriction of alimentary canal; *k*, respiratory tube; *l*, *l*, transverse vessels.

same faculty of resuscitation after desiccation. On account of the slow movement of *Macrobiotus*, they have been called Tardigrada; an objectionable term, because applied to a family higher up in the scale of development. On account of their habit of crawling, and not swimming as the great mass of Rotifers, Dujardin names them *Systolides marcheurs*. They are interesting as connecting the Rotifers, not only with the Annelida, but also, through their four pair of feet, with the higher forms of the Articulata, and on the other side with the Helminthida. Ehrenberg regards Macrobiotus not as a Rotifer, but as an animal related to *Lernæa*. This epizoon and its congeners have undoubtedly more affinity with the articulate than with the molluscous tribes; and the relation of the Tardigrades with the Rotifers establishes for that family a more decided tendency towards the articulate groups than any other.

Although the organisation of the Rotifera is included in too small a space to permit of dissection, the transparency of their integuments is so great as to permit of an easy examination of their internal organs. From the previous descriptions of the families of this order, it will be seen that their organisation is very complicated, and that their size is by no means the measure of their position in the animal scale.

Tegumentary system.— The Rotifers are all covered with a resisting tegument, more or less flexible, and which is the last part of the body to decompose. The composition of this tunic, although possessing various degrees of density, appears to be entirely organic; and the absence of siliceous or calcareous matter will account for these animals being never seen in a fossilised state. The investing membrane is open in front, to allow of the contact of the fleshy interior with the water in which the creatures live. There is, also, an anal orifice. In those species in which this membrane is not hardened, so as to form a shield, it is capable of being folded by the action of the muscles, and possesses a number of false articulations. The anterior part, to which are attached the vibratile ciliæ constituting the rotatory organ, is capable of being retracted into, or thrust out from, the rest of the body. All the parts of the body retract within the skin into a kind of globule, when the animal is removed from the water. The tegument has attached to it various organs, as the claws in *Emydium*, the cirrhi, or fins, of *Polyarthra*, and the elongated setæ of *Triarthra* (*fig.* 297.), the teeth in the dense tegument, or lorica, of *Brachionæa* (*fig.* 296. *g*, *g*). The tail, or foot, must be regarded as an elongation of the tegument. It varies much in size and length. Sometimes it consists of a single styliform seta, as in *Triarthra longiseta* (*fig.* 297.); in the genera *Monura* and *Monostyla* it is styliform, but is also articulated. In some of the species of the genus Anuræa there is no tail at all. In most instances the tail is forked, as in *Hydatina*, *Euchlanis*, *Philodina*, *Rotifer*, *Brachionus*, *&c.* (*figs.* 293—296.). Sometimes the tail is divided from the point of its origin with the tegu-

Fig. 297.



Triarthra longiseta. (*After Ehrenberg*).

a, *a*, muscular fibres; *b*, contractile vesicle; *c*, *c*, intestinal glands.

ment of the body, as in *Notommata longiseta* (*fig.* 298.) and in *Hydatina senta* (*fig.* 293.). More frequently a portion intervenes between the body and the terminal processes. This is soft and movable in every part in *Brachionus pala* (*fig.* 296.); forms a series of sheaths

in others, as *Dinocharis paupera* (*fig.* 302.), and many of the Philodinæa. The tail is

Fig. 298.

Notommata longiseta.

a, single eye; *b*, anal orifice.

often furnished with supplementary setæ, or bristles, and in *Pterodina* it is terminated with a row of vibratile cilia. The tail is used as a rudder, an oar, and a hold-fast. When styliform, it seems used as a rudder, although in some cases apparently employed to propel the animal. When furcated it has the power of opening and closing the processes on each side, and apparently holding on to any object by their means. Many genera, as *Conochilus*, *Floscularia*, *Stephanoceros*, and others, have no fork, but remain fixed by their tails. Even in species which have forked tails, as in the Philodinæa, the creatures seem to have the power of fixing themselves independently of their fork. It would thus seem not improbable that the tail in these cases acts as a kind of sucker.

Fig. 299.

Rotifer vulgaris. (*After Ehrenberg.*)

a, orifice of proboscis; *b*, eyes; *c*, probiscoid process; *d*, spur or respiratory tube; *e*, jaws; *f*, alimentary canal; *g*, *g*, *g*, *g*, transverse vessels; *h*, muscular fibres; *i*, *i*, seminal canals; *k*, young animal.

Projecting from the upper part of the external tegument, in many species, is a little process, which Ehrenberg calls a spur, or siphon (*fig.* 299. *d*), and which he thinks is connected with the function of respiration, and therefore calls it a respiratory tube. It corresponds with an orifice in some species (*fig.* 293. *g*), which Ehrenberg calls the respiratory orifice. He has also hinted that they may be connected with the reproductive function. Two of these organs are seen in some of the *Notommata* and other genera, and they are sometimes covered with cilia. Dujardin thinks that they resemble more closely the palpi and antennæ of the Entomostraca.

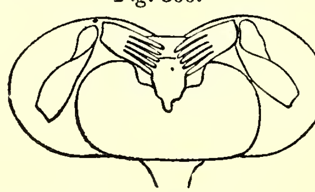
The rotatory organs, or wheels, must be also regarded as a portion of the tegumentary system. They are fleshy retractile lobes, covered with vibratile cilia, capable of being contracted or expanded at the will of the animal. The movement of the cilia when the lobes are expanded gives the appearance of a wheel moving upon its axis, an appearance which was a source of much wonder to the earlier observers of these creatures. In addition to the vibratile cilia, there are frequently found, on the rotatory lobes, setæ, or bristles, which have not the power of moving. This is the case in *Floscularia*, if, indeed, the organs called rotatory in that genus are truly homologous with the rotatory organs in other species. The true homologue of the rotatory apparatus in Floscularia appears to us to be seated within the external ciliated lobes, where an evidently active motion is constantly going on. The form of the lorica varies greatly; in some species it is flat and depressed, as in *Pterodina* and *Monostyla;* in others it is prismatic, as in *Mastigocerca*, or gaping, as in *Euchlanis* (*fig.* 294.). Some species, as *Stephanoceros* (*fig.* 292.), *Floscularia*, *Melicerta*, and others, have a soft skin, very contractile, which secretes externally a case, and which Ehrenberg calls a lorica; but this is essentially a different organ from the lorica. Where this case occurs, it seems to stand in the same relation to the animal as the Polypidon of the zoophytes. The animals which form these cases are also fixed, and retract their bodies within their case in the same manner as the Polypiferæ. The *Floscularia* may be compared to the Hydroid Polyps, while *Stephanoceros*, with its ciliated tentacula-like processes, would appear to have a relation with the Ascidoid polyps.

Motory system. — As the movements of the Rotifers are rapid and various, so we find their muscular system complicated. The principal organs of locomotion are the rotatory organs, by which alone the great mass of the Rotifers appear to move. The movements effected by these organs are performed principally by the agency of the vibratile cilia. Although no tissue has yet been discovered in the cilia of the Rotifera and Polygastria, Professor E. Forbes has observed fibrous tissue in the cilia of a species of Medusæ, and there can be little doubt that the movements of the cilia, like those of organs to which muscles are attached, are of two kinds, one of which is under the control of the will, and the other not. In the Rotifera, the vibratile cilia of the rotatory organ appear to be under the control of the will of the animal. The extension and contraction of the rotatory apparatus is under the influence of longitudinal muscular bands, which are very evident in most of the species (*fig.* 293. *e,e,e,e*; *fig.* 296.; *fig.* 294. *b*). Not only is it evident, from the action of these muscles, that they are under the control of the will of the animal, but Ehrenberg has described some of these muscles as possessing the striated character of the voluntary muscles of animals higher in the scale of organisation. *Euchlanis triquetra* (*fig.* 294. *b*) and the species of *Eosphora* are those in which striated muscles have been observed. This fact is interesting in connection with Mr. Busk's observation of the existence of muscular striæ in *Anguinaria spathulata*, a form of ciliobrachiate polyps. It affords a proof not only of the relation of these two families, but also of both, to the articulate tribes rather than to the Mollusca. Mr. Busk, after the most patient research, has not been able to discover the presence of striæ in the muscular system of the Mollusca. Not only have the longitudinal bands been regarded as active agents in the movement of the rotatory organ, but also certain transverse bands. These bands (*fig.* 293. *f,f,f,f*; *fig.* 299. *g,g,g*) have been described by Ehrenberg as transverse vessels. There seems to be little proof that such is their office.

In many of the Rotifers, more especially the Philodinæa, the tail is employed for the purposes of progression. In order to effect this, it is supplied with distinct muscular bands (*fig.* 293. *e*). Muscular fibres have also been described by Ehrenberg surrounding the œsophagus, and apparently assisting the jaws in their movements, in *Conochilus* (*fig.* 289.), *Pleurotrocha*, and other species.

Digestive system. — This apparatus is perhaps more highly developed than any other part of the Rotifera. An oral and an anal orifice indicate the commencement and end of this system. It is furnished with jaws and teeth, an œsophagus, sometimes a distinct stomach, and various forms of intestinal glands. At the commencement of this system, we find a distinct masticatory apparatus, which consists generally of two semicircular pieces, to each of which is attached one or more teeth, which act upon a central plate (*fig.* 300.; *fig.* 299. *c*; *fig.* 289. *a, a*; *fig.* 296. *b*; *fig.* 292. *d*;

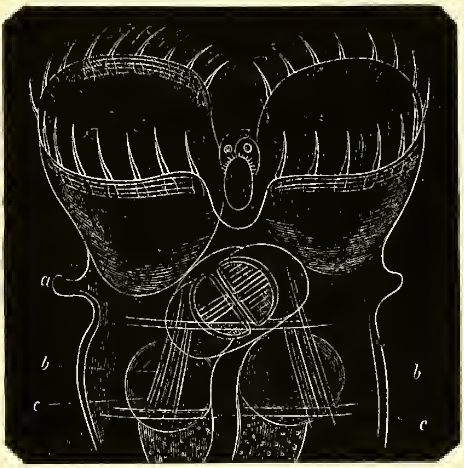
Fig. 300.



Jaws of Brachionus brevissimus. (*After Ehrenberg.*)

fig. 291. *b*). To the semicircular pieces are attached some of the longitudinal muscles, which, by their action, cause the teeth to work upon the central plate. The general structure of the jaws is, in all instances, the same, but the number of processes, called teeth, varies considerably. Sometimes no such processes are discoverable, as in *Cyphonautes;* in others, there is but one tooth on each side, as in species of *Synchæta*, *Diglena*, *Lepadella*, and *Monostyla*. Some have two on each side, as *Monocerca*, *Mastigocerca*, and *Rotifer* (*fig.* 301.). Others, again, present three, four, or several teeth on each side, as in *Brachionus brevissimus* (*fig.* 300.), *Triarthra longiseta* (*fig.* 297.), *Brachionus pala* (*fig.* 296.). Such are the characters afforded by the teeth in this family, that Ehrenberg gives an arrangement of the

Fig. 301.



Rotatory organs of Rotifer vulgaris enlarged. (*After Ehrenberg.*)

a, hornlike process (respiratory tube); *b*, *b*, muscles of the jaws; *c*, *c*, intestinal glands.

genera into orders, according to the absence or presence and number of the teeth, as follows: —

1. Agomphia. Rotifers without teeth. Examples: *Chætonotus*, *Enteroplea*.

2. Monogomphia. With a single tooth. Examples: *Pleurotrocha*, *Furcularia*.

3. Polygomphia. With many teeth. Examples: *Hydatina*, *Stephanoceros*, *Brachionus*.

4. Zygogomphia. With double teeth. Examples: *Rotifer*, *Philodinæ*.

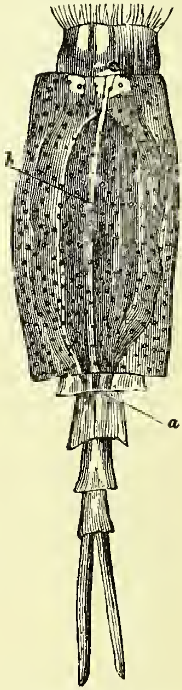
5. Lochogomphia. With teeth in rows. Examples: *Ptygura*, *Megalotrocha*.

The teeth seem to form the most dense part of the body of the Rotifera, and, after the crushing of the animalcule, may be obtained for separate examination under the microscope.

The whole masticatory apparatus is attached to the upper part of the alimentary canal, the œsophageal head, where it may be observed, being constantly in motion. This movement, which goes on whether the animal is partaking food or not, was mistaken by the earlier observers for the action of a heart. Although, in most instances, the food is brought to the jaws of the animal by the rotatory apparatus, yet we have often observed, in species of *Brachionus*, that they have the power of projecting their jaws beyond the margin of the tegumentary membrane, and bringing them immediately in contact with the substances on which they are feeding.

The form of the alimentary canal varies: it is sometimes a simple tube, as in *Dinocharis paupera* (*fig.* 302. *b*). In many species, an enlargement of the middle portion takes place from constriction of the canal, above and below, forming a kind of stomach, as in *Notommata myrmeleo* (*fig.* 303. *c*), *Brachionus pala* (*fig.* 296.). Sometimes there are two en-

Fig. 302.



Dinocharis paupera.

Back view.

a, anal orifice; *b*, alimentary canal.

largements of the canal, as in *Triarthra longiseta* (*fig.* 297.). When the enlargement takes place below alone, as in *Rotifer vulgaris* (*fig.* 299.), and *Philodina roseola* (*fig.* 295. *d*), Ehrenberg calls this portion a rectum. Ehrenberg points out the form of the alimentary canal as a mode of dividing the Rotifera, as follow: —

1. *Trachelogastrica*, those with a long simple alimentary canal.

2. *Cœlogastrica*, with a short œsophagus and an oblong conical alimentary canal, as in *Hydatina*.

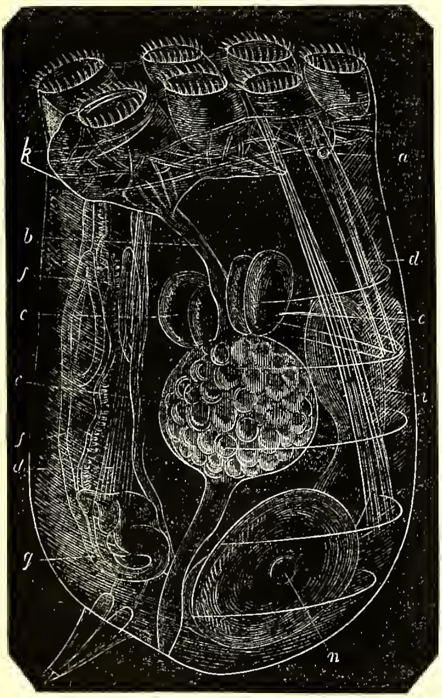
3. *Gasterodela*, in which the alimentary

canal is constructed into a bag or stomach, as *Brachionus*.

4. *Trachelocystica*, with a simple alimentary canal, enlarged at the lower part, as in *Rotifer*.

The upper part of the alimentary canal below the jaws is called by Ehrenberg the œsophagus, and is said to be either long or short, according to the distance which intervenes between the jaws and the further enlargement of the alimentary canal. In some cases, as in *Stephanoceros* (*fig.* 292. *c*), there is an enlargement anterior to the origin of the jaws, which is called the crop or gizzard. Into this cavity the food is taken before it passes into the lower portions of the alimentary canal. The same organ is seen in *Floscularia*. In this animal it is evidently clothed with vibratile cilia, whose movements seem to make up for the deficiency of a true rotatory apparatus. The whole of the alimentary canal seems to be lined with vibratile cilia, for although they are too minute, in most instances, to be seen, yet the movement of objects in the interior of the canal, as well as the force and direction with which substances are occasionally propelled from the oral orifice, would lead to this conclusion. The whole of the alimentary canal is often inclosed in a mass of cellular substance, as seen in *Philodina roseola* (*fig.* 295. *c*), and *Dinocharis paupera* (*fig.* 302.).

Fig. 303.



Notommata myrmeleo.

a, the single eye; *b*, œsophagus; *c*, alimentary canal; *d*, *d*, muscular fibres; *e*, *e*, glands; *f*, *f*, respiratory processes; *g*, sexual tubes (male?); *n*, germinal vesicle in ovum; *i*, ovarium; *k*, vascular network.

Attached to the intestinal tube, and apparently enlargements of its walls, are various appendages, about whose functions there is much difference of opinion. The most constant of these bodies are seated on each side of the termination of the œsophagus. They are mostly two in number, one on each side (*fig.* 297. *c*, *c*; *fig.* 289. *c*, *c*; *fig.* 296. *h*, *h*.) Sometimes they are four in number, as in *Notommata myrmeleo* (*fig.* 303. *e*, *e*), and in other cases more numerous. Ehrenberg originally regarded these as spermatic glands, but, subsequently, he called them pancreatic glands. Grant and others have called them indifferently pancreatic or salivary glands; and if they are secreting organs at all, they probably perform the functions of these glands in higher animals. Seated lower down the alimentary canal than these, are sometimes seen other projections, having the appearance of follicles, and these have been supposed to secrete bile. Dr. Grant describes what we have called a cellular mass in *Philodina roseola*, as a number of "short, straight biliary follicles," such as are seen in many of the higher forms of Annelides. Professor Rymer Jones regards the superior as well as the lower of these appendages, as the "first rudiments of a liver." Dujardin is inclined to regard these appendages rather as cæca than glands.

Vascular and respiratory systems. — Although Ehrenberg has pointed out several structures in the Rotifera as indications of a vascular system, it is very questionable whether any circulation takes place through vessels at all. In *Hydatina senta* (*fig.* 293.), *Notommata myrmeleo* (*fig.* 303.), *Rotifer vulgaris* (*fig.* 299.), and many others, can be seen a series of transverse bands, lying directly under the tegument; in *Hydatina senta*, these are connected with a longitudinal band, and these are regarded as a dorsal vessel and its branches. Doyere, with much propriety, regards these as a musculo-cutaneous system, analogous to a system of the same kind which he has described in the tardigrade Infusoria. In *Hydatina senta*, *Notommata myrmeleo*, and some other species, there are some free longitudinal cords, connected with a fine vascular network near the mouth, and which send filiform prolongations to the alimentary canal, which Professor Owen thinks may, with more probability, be regarded as "sanguiferous organs." We must, however, express our doubts as to the existence of a vascular system in these animals at all. In some of the Rotifera, internal tubes are seen, called by Ehrenberg seminal tubes, and upon these are often placed a row of little projecting tremulous processes, on which he has bestowed the name of gills. These processes are not very numerous in *Hydatina senta* (*fig.* 293.); but they are more numerous in *Notommata myrmeleo* (*fig.* 303. *f*, *f*). The tubes on which these gills are placed, communicate in some instances with vessels at the back part of the neck, which are again in relation with the siphon to which we have before alluded, and the whole is supposed to

constitute the rudiments of a respiratory system. Whatever may be the true function of these parts, it cannot be supposed that the oxygenation of the nutritive fluid, takes place entirely in these organs. Not only is the alimentary canal supplied with vibratile cilia, but its peritoneal surface, and the cavity in which it is placed, so that on these surfaces the respiratory changes might take place quite independent of these organs. Dujardin refers the office of certain contractile vesicles (*fig.* 297. *b*; *fig.* 288. *a.*), regarded by Ehrenberg as connected with reproduction, to the respiratory function.

Nervous system and organs of the senses. — The undoubted existence of a muscular system, and in some cases exhibiting undoubted indications of the striæ seen in the voluntary muscles of the higher animals, would prepare us for the existence of a nervous system in the Rotifera. Such a system has been pointed out by Ehrenberg, and indicated in several species by ganglia and nervous cords. In *Hydatina senta* (*fig.* 293.) there is a large mass occupying the place of the supra-œsophageal ganglia in other families, and to which Ehrenberg has given the name brain. From this mass there proceed several cords, which are presumed to be nervous. There are also other ganglia in various parts of the same animal (*fig.* 293. *c*). In the expanded rotatory organ of the *Megalotrocha flavicans*, we also see nervous ganglia, from which cords diverge in several directions (*fig.* 291. *a*, *a*). Masses of the same kind are visible in the *Stephanoceros Eichornii* (*fig.* 292. *b*, *b*).

A more complicated arrangement of ganglia and nerves has been described by Ehrenberg in *Notommata clavulata.* Whilst some naturalists have admitted the correctness of Ehrenberg's conclusions with regard to these organs, others have thrown doubts on his observations altogether. It is not improbable that, with regard to some of the parts he has figured as nervous cords, that they may be more correctly referred to other systems. But, *a priori*, it was not improbable that a nervous system should exist in these animals; and it is more probable that the organs in some parts, called nerves by Ehrenberg, should be so, than that they should be anything else. Under these circumstances, we are disposed to regard the conclusion, that these knots and cords perform the functions of nerves, as the most philosophical. An objection has been urged, against regarding the white masses as nervous ganglia, that ganglia are only seen under certain circumstances, such as the association of nerves, the concentration of nervous energy, or acting as centres of perception. Ehrenberg has pointed out the frequent co-existence of what he calls ganglia with the red spots, which he regards as eyes. These spots, which are seen also in the Polygastria, are very common in the Rotifera. Sometimes there is but one, at other times two, and not unfrequently three or more. It is upon the characters afforded by the presence or absence, and situation of these eyes, that Ehrenberg has constructed his genera of Rotifera. These eyes have been attacked from many quarters. Morren has seen their red colour distributed over the whole body in various Polygastria. Dujardin objects that they are present in some species and absent in others; that they enlarge and decrease, or disappear altogether with age. Rymer Jones says, that they possess no organisation that would lead us unhesitatingly to designate them organs of vision. At the same time, the resemblance between these eye-specks and those of the Medusæ and the Mollusca, which are admitted to be organs of vision, would still, we think, give the balance of probabilities in favour of regarding these red spots as true rudimentary eyes. If then we may regard these red spots as eyes, the masses near them, on the same grounds, may be looked upon as associated nervous ganglia.

Reproductive system. — Although all observers are agreed that the Rotifera are truly hermaphrodite, they have not agreed upon the functions of many parts supposed to belong to the reproductive system. The female organs consist of an ovigerous sac or ovary, which exists very generally in the family (*fig.* 294. *c*; *fig.* 289. *d*, *d*; *fig.* 296. *c*; *fig.* 303. *i*; *fig.* 292. *f*, *f*). It is sometimes a simple sac, at others provided with two projecting processes, terminating by a narrow opening in the common cloaca. In some cases the ovary produces but one ovum; in others there are several ova. Sometimes the young burst the shell before they leave their parent, as in the *Rotifer vulgaris.* In the *Hydatina senta* and others, the eggs are deposited some hours before the young are hatched.

The development of the ova can be seen with great distinctness through the transparent shells of many of the Rotifera. Ehrenberg has detailed this process as it occurs in the *Hydatina senta.* At first the ova are seen as little vesicles filled with a glairy fluid, probably albumen. In the course of a few hours a dark speck is seen in the vesicle, which may be called the yolk (*fig.* 303. *n*). In this state the ovum becomes fecundated, and is extruded from the cloaca. Three hours after extrusion the germinal vesicle, which had before been pushed to one side by the yolk, disappears, and the yolk occupies the whole of the egg. Six hours after extrusion, a dark spot appears upon the yolk, which can be discerned to be the head of the young animal with its masticatory apparatus. In eleven hours the rotatory organs are developed, and their cilia beginning to work, the young creature moves about in its shell. At the end of twelve hours the movements become so powerful as to burst the shell.

According to Ehrenberg, the male organs consist, first, of a series of tubular prolongations, some of which we have seen are covered with the tremulous gills, and, second, of vesicles which are capable of contracting. In some cases the tubes are present without the vesicle; in other cases, as in *Ptygura melicerta* (*fig.* 288. *a*), the vesicles a reseen but not the tubes. Those who regard these as a male

apparatus, suppose that the spermatic fluid is secreted in the tubes, and passed on to the vesicle, where it is projected into the cloaca, and fecundates the ovum. The constant contraction of the vesicle seems opposed to the view that its function is that of merely fecundating the ovum, and Dujardin thinks it is connected with the function of respiration. Hitherto no spermatozoa have been found in these organs, although Doyere states that he has found zoospores in the tardigrade Infusoria. The spermatic tubes are seen in *Rotifer vulgaris* (*fig.* 299. *i*, *i*), in *Hydatina senta* (*fig.* 293. *h*), and *Notommata myrmeleo* (*fig.* 303. *f*, *g*).

After the extrusion of the ova from the cloaca in many species, they are attached to the lorica, as in *Brachionus pala* (*fig.* 296, *f.*), in the same way as in some Crustacea. The rapidity with which the ova are produced is very great; and one individual, in the course of a few days, will be the parent of many millions. Their reproductive powers, however, are small compared with those of Polygastria.

In this brief sketch we have occasionally alluded to the affinities of the Rotifera, and we think that there can be little doubt, that these are decidedly with the Articulata, standing perhaps between the cilio-branchiate Polyps on the one side, and the Cirrhopoda on the other. Ehrenberg has summed up the general relations of these creatures in the following manner. They are

Polygastria, with a single intestinal canal, without the power of spontaneous fission.

Acalepha, with a simple intestinal canal, and rotatory organs.

Nematoid worms, with rotatory organs and united sexes.

Bryozoa, without gemmiparous reproduction.

Mollusca, without vascular pulsations.

Entomostraca, without pulsation or articulated feet, and hermaphrodite reproduction.

Fishes without a backbone or a heart, and with rotatory organs and united sexes.

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RUMINANTIA. (See Supplement.)

SALIVA

SALIVA (*la Salive*, Fr.; *der Speichel*, Germ.; *la Sciliva*, Ital.). — The saliva is a fluid secreted by a series of glands placed about the max.llary region. These glands, viz. the parotids, submaxillaries, and sublinguals, pour their secretions into the cavity of the mouth on either side. In consequence of this arrangement, it has always been a matter of difficulty to obtain saliva in a perfectly pure state, the secretion of the mouth interfering, by admixture, with the exhibition of the natural qualities of the saliva, and more especially with its microscopic characters. It occasionally happens that the fluid can be obtained more directly from the gland in cases of salivary fistula affecting the parotid duct, but it is to be doubted whether we ought to look for the secretion in its normal state in such instances. No attempts have, as yet, been made to determine whether or not saliva, as obtained from the different glands, is identical in character; but so far as general observation guides us, there appears no variation in its constitution as secreted from these different sources.

Quantity.—The quantity of saliva secreted during the day has never been very accurately ascertained. It has been said that about twelve ounces are produced during the twenty-four hours, but it is highly probable that much more than this is excreted by the adult in health. The data for the statement above mentioned are most imperfect. Mitscherlich made experiments on a patient suffering from fistula of the stenonian duct, and succeeded in obtaining about $2\frac{1}{3}$ ounces troy of saliva from the one parotid in twenty-four hours. The saliva collected during the same time from the mouth amounted in this experiment to six times more than that collected from the one gland: we may, therefore, conclude that the subject of this experiment was secreting from 16 to 20 ounces troy of saliva during the twenty-four hours. Mitscherlich observed that when the nerves were not excited by the motion of the muscles of mastication, or of those of the tongue, no saliva flowed, but that motion of these parts induced secretion.

The presence of food in the mouth caused a rapid flow of saliva, which was more especially noticed when the first portions were introduced. Long mastication appeared to cause excessive secretion, and the more stimulating the nature of the food, the larger was the quantity of saliva produced.

The uses of the saliva will be best considered when we have described its general qualities.

Physical qualities. — The constitution of saliva has been investigated by several chemists. It possesses the following general physical characters: — When freshly obtained from the mouth it is opalescent, viscid, and colourless. It separates by rest into an upper stratum of clear fluid, and a lower portion made up of the same fluid in admixture with epithelium scales and mucus. Under the microscope, saliva shows the presence of epithelium scales swollen mucus globules, and substances of various forms, apparently shreds of scales and ruptured cells. There are also fatty particles, varying in size, and bright granules. Some of the mucous

globules are remarkably transparent, and smaller than the more opake.

Specific gravity. — The specific gravity of healthy saliva is about 1007·9, according to the experiments of Dr. Wright. It is denser after food has been taken. Mitscherlich gives the specific gravity of saliva at 1006·1 to 1008·8, which agrees with Dr. Wright's observations.

Some discrepancy of opinion exists as to the reaction of saliva in respect to alkalinity or acidity. Tiedemann and Gmelin, and also Schultze, state fresh saliva to be alkaline. The latter chemist, has, indeed, attempted to define its saturating power. He also considers that it may become acid if retained long in the mouth, and that its alkalinity when fresh is dependent on ammonia. This is denied by Mitscherlich, who says that no ammonia is given off when fresh saliva is heated, and that the alkalinity depends on the presence of a fixed alkali.

I have myself found that saliva, so far from losing its alkalinity by evaporation, has this quality increased, and am inclined to regard the reaction as dependent on the presence of tribasic phosphate of soda (a salt reacting on test paper as an alkali), as has been stated by Enderlin.

Chemistry.—Berzelius estimates the solids of saliva at about 1 per cent. From the solid residue he extracted osmazome, an alkaline lactate, and chlorides of potassium and sodium by digestion with alcohol. That portion which the alcohol left undissolved consisted of soda, mucus, and a peculiar animal matter, which has been called "salivary matter," or "ptyalin." The mucus can be separated from this salivary matter and soda by digestion in cold water, which dissolves the two latter. The mucus thus separated by Berzelius yielded on incineration a large proportion of phosphate of lime.

The following is his analysis of saliva: —

Water - - - - - -	992·9
Ptyalin - - - - - -	2·9
Mucus - - - - - -	1 4
Animal extractive matter and alkaline lactates - - -	·9
Chloride of sodium - -	1·7
Soda - - - - - -	·2
	1000·0

Tiedemann and Gmelin obtained from 1·14 to 1·19 per cent. of solid residue by evaporating saliva. From this, 0·25 parts of ash were obtained, of which 0·203 were composed of salts soluble in water, the remainder consisting of earthy phosphates.

The following is a list of the constituents of the saliva, according to the above-mentioned chemists: —

1. Water.
2. A substance soluble in alcohol, and insoluble in water (fat containing phosphorus).
3. Matters soluble both in alcohol and water (osmazome, chloride of potassium, lactate of potash, and sulpho-cyanuret of potassium.
4. Animal matter soluble in boiling alcohol, but precipitated during cooling, with sulphate of potash and some chloride of potassium.
5. Matters soluble in water only (salivary matter with abundant phosphate, and some sulphate of an alkali, and chloride of potassium).
6. Matters soluble neither in water nor in alcohol (mucus, probably some albumen, with alkaline carbonate, and phosphate).

Mitscherlich gives the following analysis of the saline ingredients of saliva:

Chloride of potassium - per cent.	0·18
Potash (in combination with lactic acid) - - -	0·094
Soda - - - - - -	0·024
Lactic acid - - - - -	
Soda (combined with mucus) -	0·164
Phosphate of lime - - -	0·017
Silica - - - - - -	0·015

Simon made an analysis of his own saliva, and gives the following as the result:

Fat containing cholesterine -	0·525
Ptyalin with extractive matter -	4·375
Extractive matter and salts -	2·450
Albumen, mucus, and cells -	1·400
Water - - - - -	991·225

Simon* adopted the following process in order to complete the above analysis. A known weight of saliva was first evaporated to dryness; the loss of weight thus indicated the proportion of water. The residue was treated with ether, which extracted the fats. The solid mass remaining was next treated with water, which dissolved out the ptyalin, extractive matters, and salts, leaving behind mucus, albumen, and cells.

Dr. Wright has experimented on saliva most industriously, and has entered at some length on the peculiarities of ptyalin, but evidently speaks of a very different constituent to that described by Berzelius and Simon. According to the mode of analysis adopted by these two latter chemists, the ptyalin of Wright will be estimated with the fatty constituents, among which it most probably holds its proper place.

His process of extraction is as follows:—"To pass saliva through ordinary filtering paper, and after filtration shall have been completed, to exhaust the residue with sulphuric ether; the ethereal solution contains a fatty acid and ptyalin. It is to be allowed to evaporate spontaneously, and the residue left by evaporation is to be placed upon a filter and acted upon by distilled water, which dissolves the ptyalin and leaves the fatty acid. If the aqueous solution be carefully evaporated to dryness, the salivary matter will be obtained in a pure state. Ptyalin, thus prepared, is a nearly solid matter, adhesive, and of a yellowish colour; it is neither acid nor alkaline, readily

* In framing this article, much valuable information has been derived from Simon's work on Physiological and Pathological Chemistry, translated by Dr. Day for the Sydenham Society.

soluble in ether, alcohol, and essential oils, but more sparingly soluble in water. It possesses the odour of saliva, and is precipitated by diacetate of lead, nitrate of silver, and slightly by acetate and nitrate of lead, and by tincture of galls; neither bichloride of mercury nor the strong acids precipitate it. The latter decrease its solubility, and heighten its odour, while alkalies render it more soluble, and give it the odour of mucus. Ptyalin, when pure, may be kept a length of time, at a moderate temperature, without undergoing decomposition."

According to Dr. Wright, saliva possesses the property of absorbing oxygen gas, and he states that he has known as much as 2·25 times the bulk of the saliva to be taken up. This quality varies, however, in different specimens; in Dr. Wright's opinion, according to the quantity of carbonic acid gas contained in the secretion.

He states he has succeeded in obtaining oxygen from saliva by applying heat, and considers its presence of great value in assisting the action of the secretion during the process of digestion, inasmuch as he found that, after exposing saliva to oxygen, so as to enable it to absorb the gas freely, he was enabled to convert, by its use, a much greater quantity of starch into sugar and gum (an action of which I shall hereafter treat), than by using saliva which had not been exposed to oxygen.

Dr. Wright's analysis of saliva is as follows:

Water - - - - -	988·1
Ptyalin - - - - - -	1·8
Fatty acid - - - - -	·5
Chlorides of potassium and sodium	1·4
Albumen combined with soda -	·9
Phosphate of lime - - - -	·6
Albuminate of soda - - - -	·8
Lactates of potash and soda -	·7
Sulphocyanide of potassium -	·9
Soda - - - - - -	·5
Mucus, with some ptyalin - -	2·6

L'Heritier made analyses of saliva as obtained from healthy persons, and gives the following as a mean of ten observations on adults:

Water - - -	986·5
Organic matter - -	12·6
Inorganic matter - -	·9

Of the organic matters 2·5 parts consisted of salivary matter, or ptyalin (probably not the ptyalin of Dr. Wright, but that described by Berzelius and Simon).

Saliva of Children.— Observations by L'Heritier on the saliva of children showed the quantity of water to be greater in early life. He gives the following as the mean of four analyses:

Water - - -	996·0
Organic matter - -	3·5
Inorganic matter - -	·5

The ptyalin contained in the organic matter amounted to only 1·1.

Male and Female Saliva.—L'Heritier states that he could detect no difference between the saliva of men and women.

Enderlin has made several analyses of the ashes obtained from different specimens of saliva, and has found them to be similarly constituted.

In his opinion, the tribasic phosphate of soda it contains is valuable as a solvent of the protein compounds. He denies the existence of alkaline lactates, not only because the ashes of saliva yielded no carbonate in his experiments, but because he failed in detecting them by direct observation before incineration. His analyses of the ashes of saliva, as obtained from a large quantity of the secretion from different persons, yielded the following result:—

Tribasic phosphate of soda - -	28·122
Chlorides of potassium and sodium -	61·930
Sulphate of soda - - - - -	2·315
Phosphate of lime, Phosphate of magnesia, Peroxide of iron - -	5·509

The existence of the sulphocyanide of potassium in the saliva is a matter of importance, and some difference of opinion is observed among chemists on the subject. The discovery was originally announced by Treviranus, who noticed that saliva, when mixed with a neutral solution of the peroxide of iron, produced a dark red colour. This he regarded as produced by an acid, to which the name of "acid of the blood" had been given by Winterl, and which was afterwards known as the sulphuretted chyazic acid of Porrett. Tiedemann and Gmelin examined into this question, and found that the reaction described by Treviranus really occurred on adding persalts of iron to saliva, and made experiments to discover whether the colouration was produced by a sulphocyanide. After lengthened observation, these physiologists arrived at the conclusion that such was the case, and procured other reactions besides such as were obtained by testing with iron, which satisfied them of the presence of sulphocyanogen.

Dr. Wright mentions sulphocyanide of potassium in his analysis of saliva, and states that its quantity is always increased by locally stimulating the salivary glands, as by smoking or chewing sialogogues. The internal use of prussic acid or salts containing cyanogen increases its quantity. It is also greatly increased by the use of sulphur. Dr. W. says the presence of this salt is best detected in the alcoholic extract obtained from dried saliva. The sulphocyanide of potassium constitutes, according to his observations, from 0·051 to 0·098 of the secretion. Kuehn tried to detect the presence of a sulphocyanide in saliva, but failed. He could not prove the presence of sulphur either by the processes of Gmelin or Ure. Müller, also, was not satisfied by his observations that the red colour produced in iron resulted from the presence of sulphocyanogen.

The properties and physiological uses of the saliva have been examined into by a great number of observers, and we find much valuable and curious matter for consideration in their general results.

General Properties. — Boerhaave and Hoffman ascribed a peculiar fermentative power to saliva, a subject which was subsequently more fully entered upon by Sir John Pringle and Dr. Macbride. The former observer experimented on certain anti-putrescent qualities of the secretion, and found that raw meat putrefied slower after admixture with saliva. Another experiment of Sir John's deserves description in detail. He took two drachms of fresh meat, and the same quantity of bread, and to these added as much saliva as he supposed might be necessary for digestion. He beat up this mixture in a mortar, then enclosed it in a phial, and set it in a warm atmosphere for about two days. No signs of fermentation could be detected at the end of that time, but during the third day the bread and flesh rose in the water, a sediment formed, and bubbles were observed mounting in the liquor. The mixture now possessed a vinous smell. This action was observed to continue about twice as long as in a similarly conducted experiment made without saliva. In the former case the fermentation was more gradual, and when complete the mixture possessed a pure acid flavour, and had no disagreeable smell.

Notwithstanding that the subject has been laboriously investigated by some of the most ingenious experimenters of the day, the uses of the saliva in the economy are evidently still but imperfectly ascertained. Spallanzani was inclined to believe in a solvent action which this fluid was capable of exerting on animal matters, and thought that food, when inclosed in a tube perforated with numerous small holes, and placed in saliva, was more rapidly broken up and dissolved than when water only was used. The further observations of Berzelius and Müller tended, however, to impugn the correctness of this opinion, pure water acting, according to their experiments, quite as efficiently as saliva.

Some experiments have been made by Hünefield, by which he thinks he has shown saliva to possess a peculiar action on fibrin: this, however, requires confirmation. In the year 1831 Leuchs made a most important discovery in connection with the history of saliva, viz., that when boiled starch is added to it, and the mixture is kept at a temperature of 98°, the starch becomes converted into sugar. This action has been since investigated by Mialhe, who attributes the phenomenon to the presence of a peculiar proximate principle existing in saliva, to which he has given the name of animal diastase, in consequence of its possessing the qualities of that principle as it exists in the vegetable kingdom, in germinating seeds. In order to obtain this substance the saliva is to be filtered, and then precipitated by the addition of absolute alcohol, of which generally from five to six times the weight of the saliva are required to effect the purpose. The animal diastase falls in the form of a flocculent precipitate, which may be collected and dried on a filter. It forms about 0·2 of the whole saliva. It is a white substance, insoluble in alcohol.

A series of experiments have been lately made by M. Bernard, with a view of determining what the action of saliva may be in the digestive process.

He first satisfied himself that the saliva of the horse and the dog, as well as that from the human subject, possessed the property of decomposing starch into sugar, under the conditions of temperature above described. The saliva of the dog, however, effected the conversion but slowly, that of the horse more quickly, but neither nearly with the rapidity of human saliva. The dog's saliva required nearly eight times as long as that from man, and that of the horse nearly four times as long. Care was taken in these experiments to employ the same quantities of saliva and of starch.

Pure saliva, obtained from the parotid and submaxillary glands of the dog, were found by Bernard quite incompetent to effect the transformation of starch. This agrees with the observation of Lassaigne, who found that pure saliva from the parotid of horses possessed no transforming power of the kind, though mixed saliva taken from the œsophagus acted well on starch. According to Bernard's experiments, the explanation of this rests on the fact that the power of transformation is a property of the secretion from the mucous membrane lining the mouth, for on placing layers of that membrane in contact either with starch or sugar he obtained decomposition, and lactic acid was produced. He thus reduces the importance of saliva, as an adjunct in digestion, to little more than that of a lubricating fluid.

Saliva of Animals. — The saliva of animals has not been much experimented upon. Berzelius remarks as follows on the saliva of the dog*: — "As obtained from the parotid, it is a pale yellow fluid of mucilaginous consistence, resembling white of egg in its physical characters. It leaves 2·58 per cent. of solid matters on evaporation. These solids form a transparent pale yellow varnish on the surface of the evaporating dish, which becomes moist by exposure to air. Alcohol extracts principally chloride of sodium from this mass, and, by evaporating the alcoholic solution, crystals of the chloride can be obtained nearly in a pure state, being, however, mixed with a small proportion of a yellowish substance, composed principally of lactate of soda and osmazome. Sulphocyanogen cannot be detected with certainty in the alcoholic extract, and but a trace only of its reaction with the salts of iron can be observed.

The portion of solid matter which is in-

* Traité de Chimie, vol. vii.

soluble in alcohol contains salivary matter, combined with soda, and its reactions accord perfectly with those of the salivary matter found by Gmelin in human saliva. Phosphate of potash, phosphate of soda, and a small proportion of carbonate of lime, also exist in this saliva.

The saliva of the sheep, according to Berzelius, is clear, and not adhesive, like that of the dog. It has a feeble saline taste, and a faint alkaline reaction. When dried, it leaves 1·68 per cent. of solid matter, which forms an opaque white membrane, and becomes moist by exposure. Chloride of sodium is extracted from this mass, in octahedral crystals, by digestion with alcohol. The salts of iron yield ample evidence of the presence of sulphocyanogen in the alcoholic solution. The portion of solid matter insoluble in alcohol, when treated with water, yields little else than salts. So completely is this the case, that the evaporated aqueous solution scarcely gives out an empyreumatic odour while being heated to redness. The mass, which is insoluble both in water and alcohol, is brittle and membranous, insoluble in acetic acid, and not gelatinised when moistened by it. The acid, however, dissolves out phosphate of lime, after which it is precipitable by the addition either of ammonia or oxalate of lime, but not by infusion of galls.

The following is an analysis of the saliva of the sheep: —

Water	98·90
Matters soluble in alcohol (extract of meat, a matter which crystallises chloride of sodium in octahedra, chloride of sodium, and a small proportion of sulphocyanide of sodium)	0·11
Matters soluble in water only (traces of ptyalin, a considerable quantity of phosphate of soda and chloride of potassium, and carbonate of soda)	0·82
Matters insoluble in water and alcohol (mucus or coagulated albumen, and a small quantity of phosphate and carbonate of lime)	0·05

The peculiar quality possessed by saliva of becoming mucilaginous and adherent, was attributed by Tiedemann and Gmelin to a solution of mucus in alkaline carbonate. This last is present in the saliva of the sheep in such abundance, that when dry it effervesces on the addition of acids. The saliva of the dog, however, contains most, and the saliva of man the smallest quantity of the salt. According to Tiedemann and Gmelin, the alkaline carbonate of human saliva is a potash salt, while the saliva of the dog and sheep contains carbonate of soda.

The alkaline phosphate contained in saliva exists in larger proportion in that of man, and of the sheep, than in that of the dog. All three contain chloride of sodium in large quantity. The sulphocyanide which exists in the saliva of man and of the sheep cannot be satisfactorily detected in the dog. Ptyalin is almost wanting in the saliva of the sheep, while that of the dog is deficient in animal extractive matter.

Lassaigne and Leuret found the same quantity, viz. about one per cent. of solid matters, in the saliva of man, the horse, and the dog.

The saliva of insects has been collected by Reuzzer*, but not in quantity to admit of analysis. It was found, however, to yield an alkaline reaction.

SALIVA IN DISEASE.

Salivary Calculi. — As the result, in all probability, of some defect in secretion, the saliva occasionally gives rise to the formation of calculous matter. Thus, what is commonly called tartar, tends to deposit upon the teeth. Berzelius has examined this substance, and found that water extracted ptyalin from it, and that the remainder was soluble in hydrochloric acid, only a small residue composed of mucus being left unacted upon. Caustic ammonia precipitated phosphate of lime, and ammoniaco-magnesian phosphate from the acid solution.

Analysis yielded the following result: —

Ptyalin	1·0
Salivary mucus	12·5
Earthy phosphates	79·0
Animal matter soluble in hydrochloric acid	7·5
	100·0

Vauquelin and Langier found one of these masses to contain

Water	0·07
Salivary mucus insoluble in acids and in water	0·13
Phosphate of lime, with traces of magnesia	0·66
Carbonate of lime	0·09
Animal matter soluble in hydrochloric acid	0·05

Salivary calculi only occasionally occur in the human subject, but are frequently observed in animals. One of these substances from the human subject yielded, according to the analysis of Poggiale, 94 per cent. of phosphate of lime, the remainder being mucus and other animal matters. Wurzer found, in a concretion from the submaxillary gland of a man, carbonate of lime, earthy phosphates, oxide of iron, and manganese.

Calculous concretions, obtained from the salivary ducts of the horse and ass, have been analysed by Lassaigne, Henry, and Caventon, with the following results: —

* Physiol. Untersuch. über die thierische Haushaltung der Insecten. Tüb. 1817.

	Caventon.	Lassaigne.	Henry.
	The Ass.	The Horse.	The Horse.
Carbonate of lime - -	91·6	84	85·52
Carbonate of magnesia -	- -	- -	7·56
Phosphate of lime - -	4·8	3	4·40
Animal matter - -	3·6	9 }	2·42
Water - -	- -	3 }	
	100·0	99	99·90

Ranula.—The disease called ranula, which was long supposed to depend upon the detention of saliva within the salivary duct, owing to inflammatory closure of its orifice, and the distention consequent upon such condition, has been lately shown by Dr. Goruss Besanez* to depend on the development of an encysted tumour within the duct. The fluid evacuated from ranula has been analysed by him, and its composition determined as follows: —

Water - - - - -	95·029
Traces of fat and chloride of sodium - - - - -	1·062
Aqueous extractive matter -	0·923
Albuminate of soda - -	2·986

This analysis shows the contained fluid of ranula to differ entirely from saliva, and places it among the products of morbid secreting sacs. Under the microscope, blood corpuscles and inflammatory exudation corpuscles were observed, none of the ordinary characters of saliva appearing. Much curious information has been collected by Dr. Wright with regard to the morbid conditions of saliva, and the production of hydrophobic disease. Among the statements made by various authors are the following. †

Hydrophobia. — Ambrose Paré agrees with Galen and Dioscorides in the opinion that morbid saliva may produce hydrophobia by contact with the second skin. The disease is stated by Cœlius Aurelianus to have been communicated to a sempstress who used her teeth to unsew the cloak of a hydrophobic patient. Schenckins states hydrophobia to have been communicated by a sword which had been used some years before for the purpose of destroying a rabid dog. Palmarius relates that a peasant rendered his children rabid by kissing them.

Magendie and Breschet succeeded in producing hydrophobia in a dog by inserting the saliva of a rabid man under the skin of the animal. Dr. Herturch found that out of fifty-nine trials, only fourteen animals became affected with real rabies. Mr. Youatt succeeded in causing hydrophobia in a healthy dog by inserting as a seton-cord a piece of silk moistened in the mouth of a hydrophobic animal. There appears but little doubt that hydrophobia is really a disease produced by a morbid poison circulating in the system; nor does the long period which occasionally elapses between inoculation and the development of the disease in any way militate against the correctness of such a view, for we are aware, from the history of other well-recognised morbid poisons, how various the period required for development of action is; probably bearing some relation to the temperament and general habits of the subject affected.

Dr. Wright believes that there is no chemical difference (or, rather, none admitting of detection) between healthy saliva and that secretion which is capable of producing hydrophobia. He has succeeded in producing rabies by injecting healthy saliva into the veins of animals, and it appears probable from his observations, that the difference between saliva capable of producing hydrophobia, and the fluid in its normal state, must be regarded rather as one of degree than in kind.

Infection.—Saliva is said to have produced disease by contact in a variety of ways; with how much truth appears most uncertain, but the following statements are related as matters of fact:—

Syphilis is said to have been communicated by kissing, and by the morbid saliva adhering to a drinking cup. Lassius, Wedelius, and Victor Schneider are of that opinion. Phthisis, according to Bernhard Gladbach, has been communicated by means of the saliva; and scurvy, also, according to Rolfincius, Sennertus, and Michael. Ledelius states that an old woman infected a boy with ague by giving him bread to eat which she had previously mumbled. Many other equally strange and disgusting statements of this kind have been put forth by old writers, which show little else than the imperfect method of inquiry which satisfied the older investigators, and a lamentable inclination on their part to regard coincidences as of necessity bearing the relation of cause and effect.

The saliva is stated to become coloured occasionally, but the subject requires further investigation. Drs. Thomson and Christison have noticed it of a blue colour under the use of lead, and Dr. Wright says that ordinary medicinal doses will produce that effect. The same observer has noticed a deep blue coloured saliva in purpura and advanced stages of fever, and is of opinion that prussian blue is the cause, but has not yet examined the point. Great acridity of saliva has been observed in maniacal patients. Dr. Wright has recorded that such saliva is sometimes so irritating as to be capable of excoriating the hand when applied to it.

Children's saliva may become so acrid as to excoriate the nipples of any nurse who may suckle them.

Mercurial Salivation. — Simon has obtained acetic acid from saliva discharged during salivation, and believes it may also exist in rheu-

* Heller's Archiv für Phys. und Patholog. Chemie und Mikroskopie, vol. ii.

† See Dr. Wright's communications to the Lancet, 1844.

matism. Donné says the saliva becomes acid in many forms of disease. Brugnatelli found oxalic acid in the saliva of a phthisical patient. The following is Simon's analysis of the saliva of mercurial salivation (it contained acetic acid which was volatilised during evaporation):

Water - - - - - -	974·12
Yellow viscid fat - - - -	6·94
Ptyalin, extractives, and traces of casein - -	3·60
Alcoholic extractives, and salts -	7·57
Albumen - - - - -	7·77

This saliva, therefore, differed from that of health in containing excess of solid constituents, arising from excess of fatty matter, extractives, albumen, and salts. The ptyalin remains much as in health.

L'Heritier gives the following as the mean of three analyses of the saliva in mercurial salivation.

Water - - -	970·0	instead of	986·5 health.
Organic matters	28·6	„	12·6
Inorganic matters	1·1	„	1·9

L'Heritier, like Simon, found no great variation in the amount of ptyalin.

Dr. Wright found a great increase in the quantity of mucus contained in the saliva during mercurial salivation. He could not detect mercury in the secretion. His analysis is as follows :—

Water - - - - - -	988·7
Ptyalin - - - - - -	1·9
Fatty acid - - - - -	0·4
Albuminate of soda - - - -	0·6
Mucus, with a trace of ptyalin -	3·8
Lactates, Phosphates, Hydrochlorates, Hydrosulphocyanate } potash, soda, lime	2·4

Gmelin found a considerable variety in the saliva of patients who had been salivated by mercurial inunction. In one case a large quantity of fat was detected by him. He obtained mercury from this saliva.

Spontaneous Salivation. — The saliva of spontaneous salivation has been examined by Vogel, who found it constituted as follows :—

Water - - - - -	991·2
Ptyalin, osmazome, fat, and albumen - - -	4·4
Salts of soda, potash, and lime	4·4

This shows no great variation from the natural standard.

Mitscherlich and Guibourt, who also examined the saliva of spontaneous salivation, found no increase in the solid constituents, while the sulphocyanogen and ptyalin were deficient.

Simon examined the saliva of a patient suffering from inflammation of the pancreas (?). It was a clear viscid fluid secreted in great abundance. It contained mucus, and was of alkaline reaction. Its specific gravity was 1005.

Under the microscope, numerous oil vesicles were visible, besides ordinary mucus, globules, and epithelium scales ; 1000 parts of this saliva yielded 10 parts of solid matters.

L'Heritier examined the saliva of chlorosis, and found it to suffer from watery degeneration, in the same manner as the animal tissues and secretions generally.

In dropsy, with albuminous urine, the saliva was found by L'Heritier to contain,

Water - - -	985·9
Organic matter - -	13·6
Inorganic matter - -	·5

The amount of water contained in saliva appears to diminish in inflammatory affections. The following is a mean result obtained from six analyses made on the saliva of cases of inflammatory fever, pneumonia, and erysipelas :

Water - - -	968·9
Organic matters - -	30·0
Inorganic matters -	1·1

The proportion of ptyalin was found increased.

Scherer analysed the saliva of a girl suffering from a scorbutic affection of the mouth. There was a large secretion, forty ounces flowing in the twenty-four hours. It was fetid and alkaline, and of specific gravity 1004.

Analysis yielded the following result :—

Water - - - - -	988·8
Casein - - - - -	6·5
Fat - - - - - -	0·6
Extractive matter and ptyalin	1·8
Carbonate of soda - -	1·2
Chloride of sodium - -	0·7
Phosphate of lime - -	0·4

Confervoid growths and infusoria were detected in this saliva as taken fresh from the patient.

A specimen of saliva from a phthisical patient was examined by Landerer*, who found it to contain a great number of small fat globules aggregated into a viscid mass. These globules exhibited the properties of oleic acid.

Several kinds of diseased saliva have been analysed by Dr. Wright, and I shall subjoin his analyses.

FATTY SALIVA.

Water - - - - - -	987·4
Ptyalin - - - - - -	·7
Adventitious fatty matter and fatty acid - - -	3·9
Albuminate of soda - - -	1·5
Sulphocyanide of potassium -	a trace
Mucus - - - - - -	2·4
Lactates, Hydrochlorates, Phosphates - } potash, soda, lime -	1·8

SWEET SALIVA.

Water - - - - - -	986·9
Ptyalin - - - - - -	·3
Fatty acid - - - - -	·2
Muco-saccharine matter - -	5·6
Albuminate of soda - - -	·4
Sulphocyanogen - - -	a trace

* Heller's Archiv. 1846, p. 297.

Mucus, with trace of ptyalin			2·6
Lactates	potash		
Hydrochlorates	soda		1·9
Phosphates	lime		

An excessive sweetness of the saliva has been observed in some cases of phthisis. It was an indication to which some importance was attached by the late Dr. Cholmeley, of Guy's Hospital.

BILIOUS SALIVA.

Water		986·7
Ptyalin		0·5
Fatty matter and fatty acid		1·3
Biliary matter		3·2
Cholesterine		0·4
Albuminate of soda		1·9
Mucus		1·6
Carbonates	potash	
Hydrochlorates	soda	2·3
Phosphates	lime	

GELATINOUS SALIVA.

Dr. Wright considers this variety of saliva was known to Baglivi. He describes it as imperfectly transparent, dingy-looking, viscid, and tremulous when cold. It decomposes readily, and is above the natural specific gravity, being 1009 to 1010. It has a mawkish taste and greasy odour, giving no odour of ptyalin when heated. It contains that principle, as well as sulphocyanogen, however, though in smaller proportion than healthy saliva.

Gelatinous saliva is neutral, or faintly acid; absorbing oxygen sparingly, and possessing but little digestive power. Dr. Wright considers it indicative of a depraved and debilitated state of system. He saw one instance in a case of scurvy, and another in a case of carcinoma uteri. The analysis is as follows:—

Water		987·2
Ptyalin		·6
Fatty acid		·8
Gelatine		3·6
Albumen and soda		1·3
Sulphocyanogen		a trace
Mucus		2·5
Lactates	potash	
Hydrochlorates	soda	1·7
Phosphates	lime	
Loss		2·3

MILKY SALIVA.

This kind of saliva has been noticed by several authors. A case is related by Nuck in which, during four months, milky saliva was secreted by a woman who became gravid during lactation. When the flow of milky saliva commenced, an intumescence of the breast was observed to decline. Richard, speaking of milk fever (Ann. Clin. de Montpellier), says the malady occasionally terminates favourably by the occurrence of a salivation consisting of milky saliva. Other authors also have noticed the occurrence of milky saliva, in connection with a suppressed flow of milk from the mammary gland.

Dr. Wright describes milky saliva as white, completely opaque, neutral to test paper, and rendered curdy by acetic acid.

URINARY SALIVA.

This variety of saliva has been described by Dr. Prout. The salivation occurred spontaneously. The patient suffered anorexia, and was weak, but otherwise healthy. The renal secretion was diminished, and the saliva had a urinous taste. It was opalescent, foamed when agitated, and was slightly ropy. Its specific gravity was 1005. It restored the blue colour to reddened litmus paper. The soluble salts of lead, mercury, and silver, caused precipitates when added to it, as did also the mineral acids. Dilute acetic acid caused a precipitate, but no further precipitate could be obtained by subsequent addition of a solution of ferrocyanide of potassium. Therefore no albumen was present. 1000 grains of this saliva, when evaporated to dryness at a temperature between 212° and 300°, left 8·65 grains, which were composed as follows:—

Animal matter peculiar to saliva	3·33
Alcoholic extract, apparently similar to that from the blood	1·06
Sulphuric acid	0·90
Hydrochloric acid	0·75
Phosphoric acid	0·06
Alkali—partly potash and partly soda	2·55
	8·65

In this case, when the urinary secretion was restored by the use of diuretics, the salivary discharge was proportionally diminished.

(*G. Owen Rees.*)

THE SALIVARY GLANDS (*Les Glandes Salivaires*, Fr.: *Die Speichel-Drüsen*, Germ.; *Le Glandule Salivali*, Ital.). A series of conglomerate glands, arranged in a curved manner, and following the circumference of the inferior maxilla from the posterior border of one side to that of the other, and pouring their secretion into the mouth by means of excretory ducts, are thus denominated. They present a distinctly lobulated granular appearance, the component lobes and lobules being more or less loosely connected together by areolar tissue derived from the surface, and which, though serving the purpose of an investing membrane, is not of a sufficiently definite character to constitute a distinct capsule. They have a yellowish or greyish-red appearance, and are thus at once distinguished from the soft structures with which they are in immediate connection, namely, the cellular membrane and the lymphatic glands, the former being perfectly white, and the latter pale brown.

They are three in number on either side, and are named from above downwards the Parotid, Submaxillary, and Sublingual, and have in the same direction a relation as to their size, the parotid having the largest, the sublingual the smallest, and the submaxillary an intermediate volume. Though usually separated from each other by a slight interval,

they not unfrequently impinge the one upon the other, the lower edge of the parotid appearing to be structurally connected with the posterior border of the submaxillary, and the latter forming a junction with the sublingual. An uninterrupted glandular chain then in these instances surrounds the lower jaw.

The saliva secreted by them is poured by the ducts of the two last into the floor of the mouth, and by the duct of the first into the posterior part of the side of the cavity between the cheek and the upper and lower dentar arches.

The Parotid Gland is so named from its situation in the immediate vicinity of the external ear (*παρὰ* near, and *οὖς* the ear). It fills up the space of the same name, and is consequently bounded in front by the posterior edge of the ramus of the lower jaw, behind by the meatus auditorius externus above, and the mastoid process, digastric and sterno-mastoid muscles below: internally by the styloid process and muscles attached to it, together with the internal and external pterygoid muscles: superiorly by the posterior or parotidean division of the glenoid cavity within, and the zygomatic process without: inferiorly by a line continued on a level with the lower border of the horizontal ramus of the jaw from its angle to the anterior border of the sterno-mastoid muscle. The dimensions and form of the gland can only be well ascertained after removing it from its various connections, and in so doing it will be found that its posterior surface adheres very strongly by condensed cellular membrane to the cartilaginous portion of the meatus auditorius externus, while from its inner edge will be observed a process extending between the styloid muscles and the internal pterygoid as far as the pharynx. A dense fibrous septum, the stylo-maxillary, constituting one of the fixed points of attachment of the deep cervical fascia, separates it usually from the submaxillary gland. It has a triangular or pyramidal form. The base, which is superficial and slightly convex, represents its external surface, and is covered over by a dense areolar tissue, known as the "*parotid fascia*," from which the different processes which separate the component parts of the gland are observed to proceed. The apex is the deepest-seated portion of the gland, and is represented by the prolongation already alluded to. The gland is bent, as it were, upon itself from behind forwards, so that its anterior surface presents a deep vertical groove, corresponding with the convexity of the ramus of the jaw, which is consequently overlapped by it externally and internally, in the former situation extending to a greater or less degree over the masseter, in the latter over the internal pterygoid muscle, and stylo-maxillary ligament. The part overlapping the masseter externally gives off above a process which runs between the zygoma and the duct of the gland, is horizontal in direction, and somewhat triangular in form, and is known as the Accessory Parotid Gland or "*Socia Parotidis.*" It varies as to size, extent, and relation with the gland itself. It is ordinarily about two-thirds of an inch in length, a third of an inch in the longest part of its vertical diameter, and from one-sixth to one-eighth of an inch in thickness. It is generally, as it were, an offset from the body of the gland, and has no immediate connection with Steno's duct: at other times it is distinct from the body of the gland, and opens by one or more excretory ducts into this canal. It occasionally becomes hypertrophied when the body of the parotid itself is atrophied. Cruveilhier has observed two small accessory glands, one at the middle and the other at the anterior part of the masseter muscle. The parotid measures in a vertical direction from an inch and a half to two inches, from before backwards from an inch and a quarter to an inch and a half, and from without inwards about an inch. The lobes which enter into its composition are irregularly rounded, and considerably smaller than those of the submaxillary gland. They range from the one-eighth to the one-fifth of an inch in diameter; and these again are constituted of lobules having an average diameter of about the $\frac{1}{60}$ of an inch, the smallest measuring $\frac{1}{100}$, and the largest about $\frac{1}{30}$ inch across.

The relations of the external carotid artery, and its terminal branches, the external jugular vein, the facial and the anterior auricular nerve, and the further relative anatomy of the gland, have been already fully entered into.* We may mention, however, that in the substance of the parotid, *i. e.* in the cellular tissue between its lobules a little below the surface, are embedded one or more lymphatic glands which can at a glance be recognised from the structure of the parotid by their brown colour, smooth surface, and comparative density. These glands not unfrequently undergo morbid changes, and by their gradual enlargement cause progressive atrophy of the parotid itself, and ultimately assume its anatomical position. This circumstance constitutes therefore an important element in the inquiry as to the nature of any morbid growth occupying the parotid space, but which it would be out of place here further to allude to.

The Duct of the Parotid Gland, called also the Duct of Steno, emerges from above the middle of its anterior border, accompanied by several branches of the portio dura, runs horizontally forwards across the masseter muscle as far as its buccal border, passing about half an inch below the zygoma, and immediately below the accessory gland and transverse facial artery. Having reached the anterior border of the masseter, it curves over a mass of fat between it and the buccinator; forming then a very obtuse angle, it perforates the latter, and glides between it and the mucous membrane of the mouth, which it perforates opposite the second upper molar tooth.

This terminal oblique portion is about the fifth of an inch in extent, and has justly been compared by Cruveilhier to the vesical portion of the ureter, which, after having perforated

* See Parotid Region.

the muscular tunic of the bladder, runs for the extent of an inch between it and the mucous membrane.

The parotid duct is from two and a half to three inches in length, and is covered over by a prolongation of the areolar tissue which forms the investment of the body of the gland. This can be distinctly traced as far as the point at which it perforates the buccinator, and here it is surrounded by an aponeurotic expansion derived from the tendon of that muscle, and by a series of glands continuous with the genial glands, the ducts of which open partly into it and partly into the mouth. Having removed the external cellular covering of the duct, its true middle or fibrous coat is observed, giving it a distinct opaque white appearance. It is strong, dense, and elastic. Its thinnest portion is over the oblique part of the duct that glides between the muscular and mucous lining of the buccal cavity, its thickest that covering that part of it between the buccinator and the masseter, the remainder of the duct having this coat developed to an intermediate extent. Beneath the middle coat is the mucous lining, the cylindrical epithelium of which commences, according to Henle, suddenly at the excretory orifice, and continues as far as the delicate divisions of the duct in the substance of the gland. The cells of this epithelium in the main duct range from the $\frac{1}{1000}$ to the $\frac{1}{666}$ part of an inch in their long diameter.

The parotid derives its arterial supply from the main trunk of the external carotid, the superficial temporal, transverse facial, anterior and posterior auricular: its venous, from vessels of the same name. The lymphatics terminate in the superficial and deep facial and cervical glands. The nerves are derived from the facial, the anterior auricular, and the external carotid plexus.

The Submaxillary gland, much smaller than the parotid and larger than the sublingual, is situated in the anterior portion of the digastric space. It is irregularly oblong in form, and is enclosed in a loose investment of areolar tissue more delicate than that covering the parotid. Its long axis is directed from before backwards, and is about an inch and a half in extent. Its external or maxillary surface is slightly concave, is lodged in a groove in the bone, and is in immediate contact with the mylo-hyoid nerve. The inferior or platysmal surface is in relation with the platysma-myoides and superficial cervical fascia, constituting, in fact, that part of the gland which is seen on reflecting that muscle. The internal surface, which looks slightly upwards, is in relation with the posterior third of the mylo-hyoid muscle, the tendon of the digastric, and the stylo-hyoid and stylo-glossus. The anterior extremity, which is smaller than the posterior, impinges on the anterior belly of the digastric. The posterior border is deeply grooved by the facial artery and vein, which are occasionally surrounded entirely by the structure of the gland. From the narrowest portion of the gland, which would be represented by the confluence of the inner and outer surfaces above, generally proceeds a process, longer than the gland itself, and passing along the upper surface of the mylo-hyoid muscle in company with the excretory duct, but above it, as far as the sublingual gland in front, with which it is occasionally incorporated. This process may be regarded as analogous to the accessory gland of the parotid, and like it varies considerably in size and relation to the body of the gland. In a subject recently examined, we found it represented by two accessory glands, the upper or larger being about the size of a horse-bean, embracing the posterior half of the lower border of the sublingual gland, and grooved behind by the trunk of the gustatory nerve. It opened by a distinct duct, more than half an inch in length, into the main canal about the middle of its upper border: the other accessory gland, very small, situate half an inch further back, and also communicating with the lower border of the main duct by a canal one-sixth of an inch long. The primary lobes of the submaxillary gland are much larger than those of the parotid, and the lobules have an irregularly triangular arrangement.

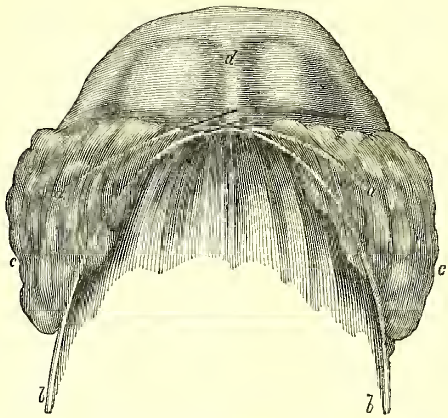
A quarter of an inch below the part at which the accessory process is ordinarily given off, appears the commencement of the excretory canal, or Wharton's duct, winding behind the posterior border of the mylo-hyoid muscle. It first lies below the gustatory nerve between it and the lingual, and after a course of a quarter of an inch, crosses the former at an acute angle, and again gets below it, resting on the hyo-glossus muscle. It accompanies the gustatory towards the tip of the tongue between the sublingual gland and the genio-hyo-glossus muscle to the side of the frænum linguæ, where it terminates. In the terminal part of its course it is directed forward, lies immediately beneath the mucous membrane, and opens by a very narrow orifice into the mouth, in the centre of a papilla of mucous membrane. This papilla forms an obvious prominence by the side of the frænum linguæ, and is situated above the eminence formed by the anterior part of the upper edge of the sublingual gland, behind the incisor teeth. The duct is about two inches in length, its coats much more delicate, and consequently more extensible, than those of the parotid. Its calibre exceeds that of the parotid duct, and, like it, its narrowest portion is that immediately beneath the mucous membrane, and this gradually contracts more and more, so that the terminal orifice becomes so small as scarcely to be visible by the naked eye. The arteries and veins that supply the submaxillary gland, are derived from the facial and lingual. The nerves are from the mylo-hyoid branch of the dental, and the gustatory, but chiefly from the submaxillary ganglion. The lymphatics communicate with the deep cervical glands.

The Sublingual gland forms a distinct eminence underneath the anterior part of the tongue by the side of the frænum. It

can be felt in the floor of the mouth, and forms a prominent ridge which elevates the mucous membrane. Its long axis is from before backwards, following, in fact, the direction of the horizontal ramus of the jaw, to which the gland is applied. The inferior surface rests upon the mylo-hyoid muscle; the external is received into the sublingual fossa; the internal is in relation with the genio-hyo-glossus and hyo-glossus below, and the mucous membrane above, the upper edge being covered by the latter. It is shaped somewhat like an almond, flattened from side to side, having its large extremity anteriorly. It is more compact in front than behind, in which latter situation its component lobes are occasionally separated the one from the other, and exist under the form of distinct irregularly rounded glands, with separate excretory ducts about a quarter of an inch in length, coming from their upper surface. The sublingual gland is from one inch and a half to two inches in its long axis, three quarters of an inch in the longest part of its vertical diameter, and about a quarter of an inch from side to side. It has a more granular feel, and its lobules, which are mutually connected by a very delicate areolar tissue, are more distinct, harder, and smaller than in either the submaxillary or parotid.

The ducts of the sublingual are very numerous, and their orifices can be seen without much difficulty, opening into the floor of the mouth, behind the movable papilla of Wharton's duct, and along the crest of mucous membrane which is elevated by the upper border of the gland from which they take their origin. They are extremely thin and delicate, and pour out, when pressure is made on the body of the gland, a distinctly viscid saliva. They range from one-tenth to one-third of an inch in length, vary much in their direction and relative situation, and are in number from 7 to 15. The anterior are very short, curve slightly on themselves from behind forwards, are about four or five in number, and some of them, according to many anatomists, form a communication with Wharton's duct, the remainder piercing the mucous membrane of the mouth. The ducts from the middle and posterior part of the gland arise at unequal intervals from each other, run in a parallel, divergent, or convergent direction, and pierce the mucous membrane by straight orifices, the posterior two or three not being longer than the one-tenth or one-eighth of an inch. They are known under the name of the Ducts of Rivinus. Bartholinus* has described another duct in connection with the sublingual gland, and which sometimes proceeds from the accessory gland of the submaxillary. It runs parallel to Wharton's duct, and pierces the mucous membrane by the side of it. It frequently opens, however, into Wharton's duct, and both terminate by a common mouth. It is by no means usually met with. In a young male, whose salivary glands we recently dissected, the duct of Bartholinus was very distinct (*a a*, *fig.* 139).

Fig. 304.



a a, the ducts of Bartholinus; *b b*, the ducts of Wharton; *c c*, the inner surface of the sublingual gland; *d*, inferior surface of the tongue.

It arose from a large lobe at the upper third of the internal surface of the sublingual gland, midway between its anterior and posterior extremity. It was nearly equal in calibre to the duct of Wharton, and was more than half an inch in length, and opened on the left side close to the orifice of that duct in the centre of the loose papilla of mucous membrane. The two orifices were so closely approximated that it was difficult to determine their individual identity. The duct of Bartholinus of the right sublingual, on the other hand, although arising from the corresponding part of the body of the gland, and being of the same length and calibre, opened at the anterior part of the crest of the mucous membrane, the one-eighth of an inch behind the orifice of Wharton's duct.

The sublingual gland derives its arterial supply from the sublingual branch of the lingual, and the submental. Its nerves are derived from the gustatory branch of the fifth. Its lymphatics communicate with the deep cervical glands.

The salivary glands, according to the researches of Huschke, are more voluminous, in proportion to the bulk of the body, in the infant than the adult, the submaxillary and sublingual, however, being proportionately larger than the parotid. In the adult, on the other hand, the parotid is, in proportion to the bulk of the body, larger than the other two.

The subsidiary salivary glands. — The labial, buccal, molar, palatine, posterior, and interior lingual glands may without any impropriety be reckoned among the glands of the salivary apparatus, being identical in their structure, and provided with excretory ducts opening on to the free surface of the mucous membrane. Varying materially in size, and irregularly rounded or flattened, they exude a

* Caspar. Bartholin. Thom. fil. deductu Salivali hactenus non descripto Observatio Anatomica. 1684.

slightly viseid saliva by their orifices, which are visible to the unassisted eye.

We have already stated that the posterior part of the sublingual gland is occasionally represented by one or more distinct glands in juxta-position, each furnished with a very short excretory duct. These distinct lobes of the gland are in every way analogous to one of the molar glands or larger labial. It will thus be observed that the transition of the primary to the subsidiary glands is by no means rapid, but that they run the one into the other by insensible gradations, the sublingual gland passing from the one series into the other. A molar, labial, or buccal gland, with its excretory duct, might then be not inaptly compared, according to its size, to a secondary or tertiary lobule of the parotid, or submaxillary.

The labial glands form a series of closely packed small spheroidal glands, of considerable density, situated in the areolar tissue between the mucous membrane of the mouth and the orbicularis oris muscle, and in relation above and below, consequently, with the upper and lower lip. They are not of uniform volume or number. Sebastian* has observed as many as fifty-seven in the lower lip, and in other instances from thirteen to twenty-one, their size increasing in the inverse ratio to their number. They are more numerous in the infant than in the adult. Their excretory ducts open perpendicularly or obliquely into the vestibule of the mouth on the posterior or free surface of the labial mucous membrane. They are not visible to the eye when the lips are in their natural lax position, but when the latter are everted, so that the mucous membrane is rendered tense, they form considerable projections.

The buccal glands are exactly analogous to the labial glands in form and position, being irregularly spheroidal, and placed between the buccinator and mucous membrane, and open by the orifices of distinct ducts on to the free surface of the latter. They are, however, smaller.

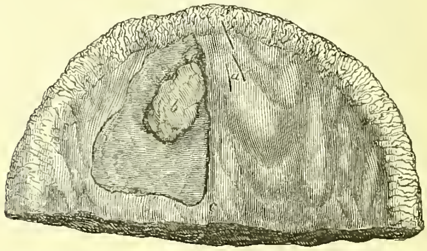
The molar glands — two, three, or four in number — form an exception as regards their situation to the above glands, being placed between the buccinator and masseter muscles. They are also larger and more dense, being composed of several lobes. The ducts terminate by opening on to the mucous membrane at the posterior part of the cheek. In a subject we recently examined, their terminal orifices were arranged horizontally at unequal distances from each other, on a level with the orifice of Steno's duct, but more than half an inch behind it. They were five in number. We have not succeeded in observing the communications which the ducts of one or more of these glands is stated by some anatomists to establish with the duct of the parotid.

The palatine glands are very numerous and small, and situated partly between the mucous membrane and the palatine arch, and partly between the mucous and muscular layers of the soft palate. The former are situated on either side of the median line, and form a thick layer, being more closely aggregated together in the front and behind than in the middle, opening on to the mucous membrane by distinct orifices. The latter, smaller than the former, exist both on the upper and lower surface of the velum, and are continuous below, where they are more numerous than above, with the glands of the hard palate.

The posterior lingual glands are placed at the back part of the tongue, directly behind the large papillæ, which form a distinct prominence at this part. They are spheroidal, and have remarkably short excretory ducts, the circular orifices of which, however, are distinctly visible.

The last glands to which we would direct attention are two in number, and from their situation may be appropriately termed the *anterior lingual glands*. They have been recently described by Blandin, Nuhn*, and Schlemm, as being situate below the apex of the tongue, between the lower longitudinal and transverse muscular fibres, and pouring their secretion during the movements of that organ on to the mucous membrane beneath the tip. They have only as yet been discovered in man and the ouran-outan. We have observed them on the inferior surface of the tongue, half an inch behind its anterior border, immediately above the longitudinal muscular fibres, one on either side of the median line, and about two-thirds of an inch long. Broad behind and narrow in front, they are separated from each other in the former direction by an interval of about half an inch, in the latter are almost in mutual contact. Their direction therefore is obliquely from behind forwards and inwards (*fig.* 305, *b*). Each gland is furnished with three or four delicate ducts, given off from its lower surface, and which perforate the mucous membrane obliquely parallel to the long axis of the gland (*fig.* 305, *a*). These glands are of less consistence than the molar or labial. We have met with one instance in

Fig. 305.



a. Bristles in the orifices of the ducts of the left anterior lingual gland. *b.* The right anterior lingual gland. *c.* The raphé of the tongue.

* Sebastian, Recherches sur les Glandes Labiales, Annales de la Chirurgie. Paris, 1842. t. vi.

* A. Nuhn, über eine bis jetzt noch nicht näher beschriebene Drüse im Innern der Zungenspitze. Mannheim, 1845, quoted by Valentin in Physiologie der Menschen, 1847, zweite Auflage.

which only one gland was present, running at right angles to the middle line. It was convex in front and concave behind, having a transverse diameter of one-third of an inch, an antero-posterior one-eighth of an inch. It gave off three delicate ducts.

The minute structure of the glands in general has been already fully inquired into *, and to the type on which they are formed the salivary glands offer no exception. A simple cæcal membranous prolongation is the model to which they can all be referred, however complex each individual series of glands may appear. This grand generalisation, by which the extreme simplicity of the operations of nature is remarkably illustrated, has mainly been the result of a minute inquiry into developmental and comparative anatomy. We are particularly indebted, however, to Müller and E. H. Weber for the exposition of the evolution and minute structure of the salivary glands.

Müller thus describes the first appearance of a salivary gland in Mammalia, and his observations were taken from the embryo of a sheep, two inches long: — Its form is that of a simple canal with bud-like processes, lying in a gelatinous nidus or blastema, and communicating with the cavity of the mouth. As the development of the gland advances, the canal becomes more and more ramified, increasing at the expense of the germinal mass or "blastema," in which it is still enclosed. The blastema soon acquires a lobulated form, corresponding to that of the future gland, and is at last wholly absorbed. Valentin† remarks that a portion of this blastema, which contains nuclei and cell-formations, and which is not converted into glandular structure, is changed into blood-vessels, nerves, and connecting cellular tissue; and he has, further, accurately determined that the secondary tubes are formed independent of the primary, at the expense of portions of the blastema, in the vicinity of the main duct, with which, by a centripetal development, they ultimately communicate. Thus, in the first stage of their development, the salivary ducts can be seen to constitute an independent closed system of tubes. The investigations of E. Weber ‡ carry us a step further in the inquiry. He found, by a successful injection of the parotid in a human fœtus, that the excretory duct, after having undergone its ultimate state of subdivision, by an extensive ramification of its secondary tubes, terminated in microscopic twigs, each twig having appended to it one or more minute cells or vesicles, forming small group-like lobules or bunches. These cells have not a uniform size, their long diameter, which is more or less in a line with the axis of each of the terminal divisions of the duct with which the cells are structurally continuous, is, on the average, almost $\frac{1}{100}$ of a Paris line. Gerber * states these vesicles or cells are variously shaped, from $\frac{1}{80}$ to $\frac{1}{100}$ of a Paris line in diameter, and upon the periphery of the gland appear mutually to compress each other and to become polyhedral in their outline. They are united together into small lobules, from four to seven times greater than each individual vesicle, the latter consequently being almost three times, the former about twelve times the diameter of the capillary blood-vessels which ramify on the surface. They form, in fact, the cæcal terminations of the branches of the excretory tubes, without having of necessity an individual narrow connecting pedicle, as figured by Berres † in the minute anatomy of the parotid.

Such, then, is the essential structure of the salivary glands; and in the full state of organisation of each we recognise the elements of a mucous membrane, constituting the internal lining of the excretory duct and continuing throughout the series of its ultimate ramifications as far as the terminal vesicles; a middle elastic coat, and an external covering of areolar tissue. The mucous membrane consists of an epithelial layer, and a basement membrane. The epithelium is of the columnar variety, and maintains this character along the track of the excretory duct as far as its delicate divisions, where it gradually changes its character, so that that lining the interior of the vesicles is of the pavement type. This transition of columnar into pavement epithelium would appear gradual; so that it is difficult to determine the point at which the one form terminates and the other commences. The basement membrane is continued along the entire track of the tubular ramifications, as far as the vesicles, the form of which it would appear to determine. There can be little doubt that this is the membrane which Berres alludes to as the proper wall of the vesicles, and describes as a small transparent membrane, covered over with molecules, and which also has been represented by Henle as homogeneous, but which he at the same time considers as composed of filaments of cellular tissue solidly united together.‡

Considerable difference of opinion has existed as to the nature of the middle coat of the glandular tubes, according as the largest or smallest have been examined. Valentin remarks that in the first case it has been considered fibrous, in the second simply homogeneous. In by far the greater number of the terminal extremities of the glandular tubes the intermediate membrane appears clear and transparent, and gives neither in the fresh state, nor when reagents are applied, any indication of a fibrous character. In all the large tubes the intermediate coat is formed of distinct flat fibres, together with the characteristic fibres of cellular tissue,

* Vide Article GLAND.

† Wagner's Handwörterbuch der Physiologie, Article GEWEBE.

‡ Meckel's Archiv. für Anatomie et Physiologie, 1827.

* Gerber, General and Minute Anatomy of Man and the Mammalia, translated by E. Gulliver, 1842.

† Anatomia Microscopica Corporis Humani, tab. ix. fig. 2.

‡ Müller's Archiv. 1838, p. 105.

studded at intervals with elongated or rounded nuclei, which present a great analogy with the fibres of organic muscle, if they be not completely identical with it. We are at present, however, in doubt as to whether the intermediate membrane of small glands, and of the terminal portion of the large, be really a simple transparent membrane, or whether it acquire, as the tubes which it envelopes enlarge, cellular and muscular fibres externally, whilst the previously transparent membrane disappears or remains as a basement membrane towards the epithelium; or whether a separation or splitting of the transparent membrane into fibres takes place. In the opinion of Henle, all the true glands having a vesicular termination, from the smallest to the most complicated, have an intermediate muscular tunic, with a series of longitudinal fibres situated within, and circular fibres without, the former being much more highly developed than the latter, and entirely absent in the more delicate ramifications of the duct. Müller, admitting the great difficulty of determining by the microscope the muscular character of the intermediate coat, is nevertheless of opinion that such is its nature, and appears inclined to believe that the frequent sudden expulsion of the saliva is attributable to it.

The cellular or areolar tissue forms an intricate network throughout the whole structure of the salivary glands, and can be distinctly traced to proceed along the course of the duct and its primary, secondary, and ultimate subdivisions. It unites together, more or less firmly, the different lobes and lobules, ultimately expanding over the primary aggregations of the vesicles of the gland, where it is lost to observation, not appearing to extend between each individual vesicle. The spaces, then, between the lobes and lobules are filled up with areolar tissue, which forms a kind of *rete* for the ramifications of the arteries, veins, and nerves.

The vascular supply.—This is derived from small branches which penetrate the areolar tissue at different points of the surface, and are conducted, as it were, by this tissue through the interlobular spaces as far as the primary aggregations of the vesicles, where they form a network, which is distributed over the elementary parts of the gland, as seen in *fig.* 306, the vascular arrangement in the parotid of a pig, from a preparation of Mr. Quekett's, and in which the capillary vessels range from the $\frac{1}{2800}$ to $\frac{1}{1150}$ of an inch.

Fig. 306.

Capillaries of Parotid of Pig.

The nervous supply. — The nerves are derived partly from the cerebro-spinal, and partly from the sympathetic system, and form a plexus around the arteries, which is ultimately lost in the interior of the gland. Their exact distribution, however, has not yet been accurately determined.

The arrangement and course of the *lymphatics* have yet to be made the subject of investigation.

The salivary glands are particularly called into play during mastication; and in order clearly to understand their relative importance, it will be necessary briefly to consider the nature of that process.

The food having been taken into the mouth, is, in the first instance, coarsely divided by the incisor teeth; and this division takes place by the alternate elevation and depression of the lower upon the upper jaw. This having been accomplished, the food is next submitted to the action of the molars, reaching the back part of the dentar arches, where the rotatory or grinding movement, brought about by the pterygoid muscles, is peculiarly exerted. Here its ultimate mechanical reduction and intimate admixture with the saliva from the parotid takes place in the following manner:—By the elevation of the jaw and the rotatory movement of the above muscles, it is alternately passed from between the two sets of teeth to between the latter and the cheeks on the one hand, and the tongue on the other. The buccinator contracting, urges it again between the two sets of teeth, from which it passes between them and the tongue, and is pushed, by the contraction of the muscles of that organ, again to its original position, between the dentar arches. These different movements are alternately kept up until the entire mass of food has assumed its requisite state of mechanical reduction, and during them the saliva flows down from the orifice of Steno's duct, becoming intimately incorporated with it, and aiding most materially in its integral subdivision.

It is worthy of remark, that the position of the terminal portion of Steno's duct, or rather that part of it which passes between the fibres of the buccinator muscle, is such that it must be pressed upon during the contraction of the muscle at that particular time when by the same action the food would be placed between the two sets of molar teeth, and the saliva not be immediately required. During the relaxation of the buccinator, on the contrary, and when the food

would be situated between the cheek and the teeth, the quantity of saliva amassed in the canal of the duct, by its temporary obliteration, would flow down and become intimately mixed up with the particles of the food, which would now entirely surround its orifice. This relation, then, of the buccinator with the duct of the parotid would seem to regulate the supply of saliva, which, if this view be correct, flows down only at a time when it can be most thoroughly incorporated with the material during its mastication. The relation of the ducts of the submaxillary and sublingual glands to this process would seem to be of far less importance. The orifices of Wharton's ducts and the sublingual ducts situated behind the incisor teeth, would appear to hold a direct relation only to the primary stage of mastication, that is to say, lubricating with the saliva the larger masses into which the food is broken up during that process, and probably after its completion, immediately prior to the passage of the whole mass into the stomach.

The position, then, of the duct of the parotid, which is so situated that mechanical means are brought into play, in order to insure the thorough incorporation of its saliva with the food, and the great comparative size of the gland itself, lead naturally to the inference that the parotid is by far the most important gland in the series, the submaxillary and lingual having but a subordinate function. This deduction has been experimentally proved by Bernard*, who, having made an aperture at the lower part of the œsophagus of a horse, administered to the animal about sixteen ounces of oats. Fifteen or sixteen seconds after the commencement of mastication, a rounded mass made its appearance at the œsophageal opening, well triturated, perfectly moist, pasty in the interior, and covered on the exterior by a moderately thick layer of tenacious mucus and saliva. A fresh quantity of the oats, in a similar condition, was projected every three-quarters of a minute. At the end of nine minutes, the mastication of the entire quantity having been finished, the ducts of the parotid were divided, so that the saliva that was secreted could be conducted out of the mouth. The same quantity of oats was again given to the animal. In this second experiment mastication did not appear to be attended with any particular inconvenience, and was performed as easily as in the first. It was exerted, however, a much longer time; for a minute and a half elapsed before the first mass made its appearance at the opening: this, though well triturated, and covered on its external surface with much mucus, was considerably smaller than those masses which had escaped from the œsophageal opening prior to the division of the ducts of the parotid. The interior of the mass, also, instead of being, like them, well moistened and pasty, had but slight tenacity, and was comparatively dry. Mastication and deglutition now became more and more difficult, lengthened, and laborious, so that an interval of from two minutes and a half to three minutes frequently occurred between the exit from the œsophagus of the successive masses. The horse, in its endeavours to swallow the oats which appeared to adhere to the palate, frequently gulped down a quantity of air, which escaped with noise from the œsophagus prior to the exit of the oats that had with such difficulty passed into the canal. At the end of twenty-five minutes, but little more than eleven ounces of the oats had been masticated and swallowed, whereas, prior to the division of the parotid ducts, sixteen ounces had been well triturated and swallowed in nine minutes. Bernard further remarks, that he collected during the second experiment the saliva that flowed from the parotid ducts, and he found that it came away in an almost continued current; but that during the time that he administered water to the animal not a single drop of saliva escaped. The circumstance of the smallness of the masses passed in the second experiment, and the dryness of their interior, taken together with their exterior envelope of tenacious mucus and saliva, which was as abundant as before the division of Steno's ducts, lead to the inference that the former condition was owing to the absence of the aqueous secretion of the parotid; the latter condition, to the fact of the submaxillary and sublingual glands being mainly engaged in the secretion of a tenacious saliva. Further experiments bring about the conclusion that the fluid from the parotid on the one hand, and from the submaxillary and sublingual on the other, are regulated by conditions special to each. Thus, the quantity of saliva secreted by the parotid of a horse is in direct ratio to the dryness of the food and the difficulty experienced in its mechanical division. The mastication of straw and hay causes the flow of more than that of oats and farinaceous matters; the mastication of moist forms of food, hardly any. This, however, is by no means the case with the saliva from the sublingual and the submaxillary ducts. This always flows nearly in equal abundance whether mastication be exerted on dry or moist forms of food, and, owing to its comparative tenacity, is not easily imbibed into the centre of the masticated material, but gathers round the surface of the mass, thus favouring its passage along the alimentary canal. In a mechanical point of view, then, there are two forms of saliva: the one clear and aqueous, secreted from the parotid, and which may be denominated the "*saliva of mastication*," because its secretion is directly related to this act; the other tenacious and secreted by the submaxillary and sublingual, "*the saliva of deglutition*," because it always lubricates the surface of the alimentary mass, whether it be submitted to mastication or not. The above views of Bernard are materially strengthened by the fact of the high development of the parotid in animals that masticate,

* Mémoires sur le Rôle de la Salive dans les Phénomènes de la Digestion. Archives Générales de Médicine, Janvier, 1847.

and its absence or mere rudimentary condition in those that swallow without masticating. Its comparative smallness, in relation to the submaxillary and sublingual in the human infant, is also corroborative.

Without entering into the physiology of the secretion of the saliva, which will be found treated of elsewhere (see SALIVA, SECRETION), it may be interesting to remark, that the salivary glands, although immediately surrounded by muscles, are not necessarily compressed in the different movements of the jaw. This conclusion has been arrived at by a series of interesting experiments and inductions due to Bordeu, but into the analysis of which it would be beyond the limits of this article to enter.*

MORBID ANATOMY. — The parotid gland is far more frequently the subject of disease than either the submaxillary or sublingual. The idiopathic inflammation of these glands is known under the name of Cynanche parotidea, vulgarly translated " mumps." The submaxillary is occasionally, and the sublingual but rarely implicated. The surrounding soft parts, particularly the lymphatic glands, participate in the inflammation, tending greatly to increase the swelling. On account of the intimate relation of the glands with the jaw, considerable pain and inconvenience form a prominent symptom. The saliva is at first increased, and subsequently diminished in quantity. Suppuration very rarely occurs. Secondary inflammation takes place as an occasional complication of the different forms of fever. In eighteen cases of typhoid Louis observed one in which the parotid was implicated. The man died on the thirty-ninth day of the attack; and nine days prior to death pain supervened in the parotid glands, which were found after death to be twice their ordinary volume, and studded throughout with small purulent deposits.

The chief point of interest, however, to the surgeon and anatomist, in connection with inflammation of the parotid, is the formation of abscess in the region of the gland. This may either take place in the subcutaneous cellular tissue superficial to the parotid fascia, or in the substance of the gland beneath that fascia. It generally occurs, in the one form or the other, in connection with phlegmonous erysipelas of the face and neck. Abscesses forming in the latter situation demand the prompt attention of the surgeon, inasmuch as they are attended with the most severe constitutional symptoms, which are only relieved by a free incision through the dense fibrous envelope of the gland: unless thus treated, the matter either makes its way through the external auditory canal, by passing between its bony and cartilaginous divisions, or, after the most severe symptoms, bursts externally in the parotid region. It may even extend deeply into the neck as far as the trachea, and terminate by effusion into the chest and — death. Independent of this extensive burrowing, matter pent up beneath the parotid fascia may exert a most injurious influence by compression of the larger vessels of the neck, the structure of the gland itself, and the facial nerve. Examples, in fact, are on record of almost complete destruction of the gland itself, and incurable facial paralysis, from neglect of incising the parotid fascia at an early period of the formation of pus beneath it.

In inflammation of the salivary glands, whether primary or secondary, the areolar tissue of the gland is most usually affected; in a few instances, however, the true structure of the gland is implicated. Berard * relates a remarkable instance of this kind, in which both the areolar and glandular tissue were affected. When the parotid was pressed, pus flowed into the mouth from Steno's duct.

Abscesses connected with disease of the ear now and then make their way into the substance of the parotid gland.

Encysted tumours are occasionally observed in the body of the parotid, and in all probability are more in connection with the lymphatic glands than the gland itself, except in those cases where they arise from isolated collections of saliva, owing to obstruction in some part of the excretory canal. The latter formations are, however, but rarely met with, and, when so, occur usually in the track of Steno's duct.

The parotid and submaxillary undergo also fibrous and carcinomatous degeneration. The latter affection, as a purely idiopathic change, is extremely rare; and, although the records of surgery afford ample illustration of such in the parotid, according to the assertions of the authors of individual cases, the evidence in some must be received with considerable reserve. Carcinoma originating in the lymphatic glands, superficially to or beneath the parotid fascia, or, lastly, in the parenchyma of the gland itself, has been, in fact, indiscriminately described as carcinoma of the parotid gland. This subject has been minutely inquired into by Berard, as also the extirpation of the gland † in a great number of the cases on record. He concludes his observations, by remarking that scirrhus of the parotid generally calls for the extirpation of the parts affected; and supports this conclusion by observing, that relapses after the operation are comparatively rare. This inference is at variance with the opinion of many practical surgeons; and it would require a much more extensive and impartial series of statistics than we at present possess to arrive at a definite conclusion on the subject. No greater difficulty exists than to obtain the subsequent history of apparently successful cases in surgery, and that of those in which the parotid has been extirpated forms no exception to the remark. In the case related by Mr. Luke ‡,

* Bordeu, Recherches Anatomiques sur la Position des Glandes, et sur leur Action. Paris, An. viii.

* Berard, Maladies de la Glande Parotide, et de la Région Parotidienne. 8vo. Paris, 1841.

† Loc. cit.

‡ London Medical Gazette, Feb. 5, 1831.

and in which there is every thing to show that the parotid was entirely extirpated, the disease returned at the end of a year, and terminated fatally. In Mr. Solly's case*, in which the ascending ramus of the jaw was removed, in order to extirpate the gland as completely as possible, the disease, instead of being confined to the parotid gland, was found, a few months afterwards, by the death of the patient, to have proceeded from the brain. Other cases, again, have been described as carcinomatous affections of the parotid, but in which their details by no means indicate that such was their nature. The case related by Larrey, for example, and which he considered to be one of carcinoma, will appear, we think, on a careful perusal, to have been nothing more than a strumous affection of the lymphatic in the substance of the gland, or possibly of the gland itself, "which had degenerated into a dense yellow lardaceous substance."†

A remarkable case of hypertrophy of the parotid is related by Tenon.‡ It had the form of a tumour, of the size of the fist, extending from the ear to the angle of the lips; it was soft, white, indolent and movable, some large vessels here and there ramifying on the surface. The arteries, on the death of the child, were found considerably enlarged, which circumstance, in all probability, accounted for the condition of the gland.

Berard also met with a similar case in a child three years old. The tumour was of almost the same volume, but simulated an erectile tumour. The veins were found very much enlarged and the arteries normal, the cellular tissue reddish and granular, and the true tissue of the gland remarkably hypertrophied.

Salivary fistulæ occur in the course of the excretory duct of the parotid, in it or its smaller ramifications, and arise from accidental injury, the result of inflammation, or from ulceration of a salivary tumour, which has gradually enlarged in consequence either of inflammatory obstruction at some part of the duct, or the presence of calculi.

Marti relates the case of a congenital deformity of the parotid duct (simulating fistula) in an otherwise healthy female infant.§ The orifice opened on the exterior of the right cheek, down which the saliva flowed.

The exact nature of *ranula* has not been clearly determined. It consists of a sublingual tumour, varying considerably in size and density. Some consider it as a mere dilatation of the duct from obstruction at its orifice; others as a submucous tumour, external to the duct, causing its compression; and others, again, as an encysted tumour developed in its interior. Although the analysis of the contained fluid (see SALIVA) would appear to indicate that the last opinion were correct, it is by no means certain whether mere obstruction at the orifice of the duct may not give rise to a similar change in the quality of the saliva.

* London Medical Gazette, Dec. 19, 1845, and July 14, 1848.

† Mémoire de l'Extirpation des Glandes Salivaires.

‡ Histoire de l'Academie des Sciences pour l'année 1760, quoted by Murat.

§ Marti, De Loco præternaturali Orificii Ductus Salivalis Stenoniani sanato. 1746.

The morbid condition of the labial glands has been made the subject of distinct inquiry by Sebastian*, who arranges their affections under the heads of — 1. Obstruction of the excretory duct. 2. Atrophy. 3. Tumefaction with hyperæmia. 4. Ulceration.

The first affection occurs under two forms: The one as a transparent painless tumour of a bluish tint, resembling a vesicle or hydatid in the substance of the lip, of the size of a pea, and containing a transparent viscid fluid. He has only met with it in the lower lip, on the right side, near the angle of the mouth, and always solitary, and of quick formation. The other form is comparatively frequent, and appears as small round elastic, more or less transparent indolent tumours, frequently as many as fifteen in the lower lip. They exude on puncture a thick, viscid, greasy matter. The second affection is distinctly remarked in the incipient stage of cancer of the lip, which, according to his opinion, commences in the cellular tissue. The third occurs in follicular duodenitis; and typhoid fever, as observed by him in children. He has frequently met with the fourth affection in phthisical individuals, &c.

COMPARATIVE ANATOMY. — The first appearance of a salivary apparatus has been observed by Owen, in a genus of *Entozoa* found in the stomach of the tiger, and named by him Gnathostoma. It consists of four elongated straight blind tubes, each about two lines in length, placed at equal distances around the commencement of the alimentary canal, having their small extremities directed forward, and opening into the mouth.†

Among the *Echinodermata* the salivary organs in Holothuria regalis are represented by elongated cæcal processes, surrounding the œsophagus, and continued into the branched tentacles around the mouth. They exude a viscid secretion, which assists in entangling the objects which constitute the food of the animal, lubricating them, and adapting them for deglutition.

In *Myriapoda* the salivary glands consist of small transparent vesicles, constituting in Julus terrestris, for example, a clavate mass, the small extremity of which terminates in a twisted excretory canal opening into the pharynx. They are large and very vascular in the Scolopendridæ.

In the *Insecta* the salivary glands evacuate themselves either into the mouth, or the commencement of the intestine in front of the stomach.

They are arranged by Burmeister as follows‡: —

* Loc. cit.

† Proceedings of the Zoological Society, 1836. p. 125.

‡ Burmeister's Manual of Entomology, translated from the German by W. E. Schuckard, p. 144.

A. Salivary vessels opening into the mouth, generally beneath the tongue, and more seldom at the base of the mandibles. They take the following forms: —

1. Simple, long, undivided, twisted tubes: thus in the majority of insects, viz. all butterflies, many beetles and flies.
2. As a narrow vessel which empties itself into one or two bladders, whence the salivary duct originates (Nepa, Cimex, Sarcophaga).
3. As a ramose vessel with blind branches (Blaps).
4. As two long cylindrical pipes, which unite into one excretory duct.
5. As four small round bladders, each pair of which has a common duct (Pulex, Lygoeus, Cimex).
6. As a multitude of such vesicles in Nepa.
7. As capitate tubes, in the free ends of which many very fine vessels empty themselves (Tabanus).
8. As tubes which at intervals are surrounded by twirling blind bags (Cicada).
9. As granulated glands which on each side unite into a salivary duct, both of which join into a single evacuating duct (Gryllus).

B. Salivary glands which empty themselves into the commencement of the stomach, as short or long bags, either simple or furnished with processes (Buprestis); other forms as well as those just cited, are found among the Diptera: —

1. As two capitate tubes, into the free ends of which many delicate vessels open (Hemerobius perla).
2. As two short processes of the same width as the stomach (Leptis and Acheta).
3. As two bags covered entirely with short blind processes (Bombylius, Buprestis).
4. As triangular processes, each edge of which is occupied by a row of vesicles (Chrysotoxum).
5. As six narrow tubes which surround the commencement of the stomach (Gryllus).
6. The blind processes which clothe the stomach in the predaceous beetles.

In *Cirrhopoda* the salivary glands are two in number and of considerable size, opening into the commencement of a short œsophagus.

Among *Pteropoda* they are found in Clio as two long and slender glands placed at the sides of the œsophagus, and pouring their secretion into the mouth. They "present in the *Gasteropoda* different forms and degrees of development bearing the ordinary relations to the construction of the mouth and the nature of the food. In the Calyptræa they are represented by two simple elongated secreting tubes. In the whelk they present a conglomerate structure, and are situate at each side of the œsophagus at the base of the proboscis, along which they transmit their slender ducts to terminate on each side the anterior spines of the tongue." (Owen.) In the snail they are flattened, elongated, and irregular in form, and conglomerate in structure, diminishing in breadth as they proceed upwards to the pharynx, where their ducts terminate. In the Vaginulus an additional slender tube which lies first on the stomach, passes through the nervous collar to join the duct by which the saliva is discharged.

The salivary glands are present in all the *Cephalopoda*, with the exception of Loligopsis. In the Onychoteuthis two glands are situated at the root of the tongue. They are in general, however, four in number, two at the root of the tongue, which give off distinct ducts which terminate at the commencement of the œsophagus; the other pair, generally longer than the superior, is lodged in the visceral sac, on each side of the upper part of the crop. The ducts of the last form a single tube which opens in the neighbourhood of the spiny portion of the tongue.

The salivary glands are absent in *Pisces*.

Among reptiles in the *Chelonian*, *Saurian*, and *Batrachian* orders, the substance of the tongue seems principally made up of a glandular mass formed by a multitude of little tubes united at their bases, but becoming separate towards the surface of the tongue. In the *Ophidian* reptiles two glandular organs placed immediately beneath the skin of the gums surround the margins of the upper and lower jaw, and pour an abundant salivary secretion into the mouth. (Rymer Jones.) In many genera the salivary apparatus is deficient. The poison glands of serpents can hardly be reckoned among the salivary organs, being destined for a special secretion, and forming the analogues to similar glands in the Arachnida.

In *Aves* the salivary glands present considerable variation in their number, position, and degree of development. In the crow the only indication of a salivary apparatus is a series of simple cone-shaped follicles, placed along the sides of the oral cavity, upon the mucous membrane of which they open by distinct orifices. In general, however, there are four pairs, two sublingual on each side beneath the tongue, two maxillary divided each into an anterior and posterior, and opening by special ducts in front of the tongue, and a gland which can be compared to the parotid. These are generally all present in the *Rapaces*, *Passeres*, and *Gallinæ*; and appear to be absent in Sula, Carbo, and Phænicopterus, and but slightly developed in the *Grallæ* and *Palmipedes* generally. In the goose they occupy the entire space included between the rami of the lower jaw, being closely united in the median line, and opening into the mouth on each side of this by a series of orifices. In the watercoot and Hirundo esculenta, the parotid is highly developed, in the latter the secretion serving for the preparation of

its edible nests. In the woodpecker the glandular mass is of extraordinary size, extending from the angle to the symphysis of the jaw on each side, and opening by the confluence of the two ducts into a single orifice at the apex of the mouth.

In *Mammalia* the salivary glands present considerable variation. In the *Monotremata* they are partially deficient: in the Echidna there appears to be no parotid; the submaxillary, on the other hand, is highly developed, extending from the meatus auditorius along the neck, and upon the anterior part of the thorax. Its ducts terminate by numerous orifices on the membranous floor of the mouth, and pour out a secretion for the lubrification of its long and slender tongue. In the *Cetacea* the salivary glands are absent. In the Dugong, however, one of the herbivorous Cetacea, the parotids are highly developed. In the *Ruminantia* the three pairs are highly developed, particularly the parotid; and in addition to these there is a group, apparently continuous with the molar, which mounts up along the superior maxillary bone, beneath the zygoma, to the globe of the eye, as observed in the ox, the sheep, and the horse. The excretory ducts pierce the mucous membrane near the posterior margin of the superior alveolar ridge.

In the armadillo, among the *Edentata*, the submaxillary gland has appended a reservoir or bladder, receiving the saliva by small ducts, which open into it posteriorly in a valvular manner. A single duct comes off from its anterior part, and terminates just behind the symphysis of the lower jaw. The saliva is very tenacious, the serous part being probably absorbed during its detention in the reservoir, and is expelled at the extremity of the mouth, in order to lubricate the tongue, which is by this means rendered subservient, as in the ant-eater, to the catching of insects. In the latter animal the salivary secretion takes place from two glands, situated, according to Cuvier, the one in contact below with the upper edge of the masseter, and filling up a great part of the temporal, zygomatic, and orbital fossæ; the excretory duct opening into the mouth behind the superior maxilla: the other, probably furnishing the viscid secretion that coats the tongue in front of the tendon of the masseter, behind the angle of the lips, and then running along the edge of the lower lip as far as the middle. Its canal opens externally at the commissure of the lips.

In the *Carnivora* the variations of the salivary glands are but slight. The submaxillary in them, as in the Rodentia and Ruminantia, are large. The sublingual gland is absent in the cat.

The writer of this article has to acknowledge his obligations to the undermentioned sources, for the preceding account of the comparative anatomy of the salivary glands: — Cuvier, Leçons d'Anatomie comparée; Owen's Lectures on the Invertebrata; Rymer Jones, General Structure of the Animal Kingdom; Wagner, Elements of Comparative Anatomy, translated by Tulk; Kelp, De Systemate Salivali, and the various articles on Comparative Anatomy in this Cyclopædia.

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(*Nathaniel Ward.*)

SCAPULAR REGION (Descriptive and Surgical Anatomy of). The term scapular region is intended by some anatomists to comprise all the structures which lie on the scapula, on its anterior as well as on its posterior surface; but, in accordance with the arrangement of Velpeau and others, we limit the term scapular region to the posterior aspect of the scapula, regarding its anterior, or subscapular, surface as appertaining to, and forming one of the boundaries of, the axillary region. Under the denomination then of scapular region, we include a portion of the posterior aspect of the shoulder, presenting a triangular outline, to which the following boundaries may be assigned. Its base, which is placed internally, is constituted by the vertebral margin of the scapula; its apex, placed externally, becomes continuous with the region of the shoulder joint; inferiorly, it is limited by the lower oblique edge of the latissimus dorsi muscle, which likewise separates it from the region of the axilla; and above, the superior costa of the scapula constitutes its extreme boundary, and separates it from the great posterior triangle of the neck.

Between the integuments and the dorsum of the scapula, which forms the floor of the region under consideration, lie numerous muscles, layers of fasciæ, vascular inosculations, branches of nerves, &c., which we shall describe in the order in which they present themselves in dissection.

The muscles, which are numerous, may be divided into the extrinsic and the intrinsic; the latter are, the fleshy portions only of the supra- and infra-spinati, and of the teres major and the teres minor muscles. Under the former class, we shall have to speak of portions of the trapezius, latissimus dorsi, and deltoid muscles. Numerous other muscles are attached to the different borders of the scapular region; but these have been already described in the several articles treating of the regions to which they more properly belong (*vide* Neck, Back, Arm). The projection backwards of the spine of the scapula naturally

divides the scapular region into two distinct parts, termed by anatomists the supra- and infra-spinal fossæ ; and in this article we shall describe, *seriatim*, the anatomical relations of the structures which occupy these two fossæ respectively.

The subcutaneous layer of areolar tissue, throughout the whole of the scapular region, is dense, and much more closely connected to the integument than to the aponeurosis beneath. Very free motion of the skin on the deeper seated structures is thus allowed. In this layer, superiorly, we find some of the superficial descending branches of the cervical plexus of nerves passing towards the region of the shoulder, where they become lost in the integument. Beneath the skin, subcutaneous areolar tissue, and superficial layer of fascia, the trapezius muscle covers all that portion of the scapular region which corresponds to the supra-spinal fossa. The fibres of this muscle take a direction downwards, outwards, and forwards, across this region, to the upper edge of the spinous process, and angle of junction between the acromion process and clavicle, into which they are inserted ; the more posterior fibres are oblique ; the anterior, coming from the superior crest on the occipital bone, descend more perpendicularly. This muscle acts powerfully as an elevator of the shoulder joint, its anterior fibres drawing the entire scapula upwards and backwards, and with it the upper extremity, whilst its posterior fibres effect the same purpose by producing a motion of rotation in the scapula, in virtue of which the posterior angle of that bone is depressed, and the anterior, or acromial extremity, proportionately elevated. In cutting through the trapezius muscle, the anatomist will probably meet with some of the terminal branches of the spinal accessory nerve distributed to this muscle ; as also descending branches of the supra-scapular artery, which, becoming superficial, maintain around the acromion process an anastomosis with the ascending (*inferior acromial*) branches of the acromial axis, and the circumflex branches of the axillary trunk.

Beneath the trapezius muscle, and separating it from the fascia which covers the supra-spinatus muscle, a layer of fatty areolar tissue is always placed, which varies, however, in its amount, in different persons. In chronic disease of the shoulder joint, such as ulceration of the articular cartilage, and, in fact, in all cases where inflammatory action has existed in the articulation for any considerable length of time, this intermuscular fatty stratum becomes absorbed ; and to this circumstance, as also probably in some degree, to atrophy of the muscular fibres, is due the peculiar flattening, or even the depression, so constantly observed above the spine of the scapula in such cases ; appearances analogous to the flattening of the gluteal region, which is one of the most remarkable external features of " morbus coxæ."

Deeper still is placed an aponeurosis of great strength, which forms, with the smooth concave surface of the supra-spinal fossa, an osteo-fibrous canal, containing the fleshy portion of the supra-spinatus muscle. This fascia is stretched between the superior costa and the spine of the scapula ; by its under surface, posteriorly, it affords attachment to the fibres of the supra-spinatus ; whilst anteriorly it accompanies the tendon of that muscle, under the acromial end of the clavicle and the triangular ligament, losing itself on the capsular ligament of the shoulder joint.

By the removal of this fascia, we bring into view the supra-spinatus muscle, filling accurately the fossa from which it derives its name, and from nearly the entire of which it derives its origin ; anteriorly, however, the muscular fibres have no ossific attachment. They here glide over the smooth, pulley-like surface presented by the bone, and then, bending downwards and outwards, they form the tendon of the muscle, which is inserted further on into the upper facette of the great tuberosity of the humerus, becoming also incorporated with the capsular ligament. In this part of their course the supra-spinatus muscle and tendon are concealed by the acromio-clavicular articulation, and more externally by the coraco-acromial, or triangular ligament, which is stretched in the form of an arch above them ; a bursa of large size intervenes between the under-surface of the ligament and the superficial, or upper aspect of the tendon. By the removal of the trapezius muscle we are also enabled to see the attachments of several muscles to the edges of the supra-spinal fossa ; thus the insertion of the levator anguli scapulæ into the posterior superior angle of the scapula becomes apparent ; also the attachment of the upper fibres of the serratus magnus anticus to its superior costa; and that of the omo-hyoid muscle to " the ligament of the notch," and the base of the coracoid process. In this situation also the supra-scapular nerve and artery enter the supra-spinal fossa, usually separated from one another by " the ligament of the notch." The nerve, in the majority of instances, being beneath, and the artery above, the ligament, the nerve is transmitted through a foramen, formed by the notch in the upper edge of the scapula and the ligament of the notch, whilst the artery enters the fossa through a small triangular interval, the respective sides of which are constituted by the ligament of the notch, coracoid process, and the posterior belly of the omo-hyoid muscle.

The *supra-scapular nerve* is a branch from the upper division of the brachial plexus : in the neck it follows the course of the omo-hyoid muscle to the scapula, passes beneath the origin of that muscle and through the foramen above described ; after which it enters the supra-spinal fossa, and is distributed, *firstly*, to the supra-spinatus muscle ; *secondly*, to the infra-spinatus and teres minor muscles, by a branch which passes beneath the acromion process ; and, *thirdly*, by a few twigs to the exterior of the capsule of the shoulder joint.

The *supra-scapular artery* (sometimes designated *arteria transversalis humeri*) has elsewhere been described as arising from the thyroid axis of the subclavian trunk; it passes at first downwards, and then nearly transversely outwards, anterior to the phrenic nerve, and between the sterno-cleido mastoid and the anterior scalenus muscles; it next runs along the base of the supra-clavicular triangle in close contact with the front of the subclavian vein, behind the clavicle and subclavian muscle, and below the level of the subclavian artery, here in the third stage; more externally it crosses this great trunk near the commencement of the axillary; it then passes in front of the *brachial plexus of nerves*, running along with the supra-scapular branch, parallel to the omo-hyoid, and covered by the trapezius muscle, to the superior costa of the scapula, where it enters the supra-spinal fossa above "the ligament of the notch." Whilst under cover of the trapezius muscle, the supra-scapular artery gives off a large muscular branch, the ramifications of which have been alluded to as assisting to form the acromial anastomosis. The final distribution of the artery is by two branches.

1. The *supra-spinal branch*, which is distributed to the supra-spinatus muscle, and which anastomoses near the posterior superior angle of the scapula, with branches from the posterior scapular artery.

2. The *infra-spinal branch*, which enters the infra-spinal fossa by passing beneath the acromion process, and the "spino-glenoid ligament" of Sir Astley Cooper; here it is distributed to the deep surfaces of the muscles of this region, and anastomoses freely with the termination of the posterior scapular, and with the posterior branch of the subscapular arteries.

The structures thus shown to be contained in the supra-spinal division of the scapular region are the following: — 1. Integument, dense areolar tissue, and superficial nerves; 2. A thin aponeurosis covering, 3. The trapezius muscle; 4. A layer of fatty areolar tissue; 5. The strong supra-spinal aponeurosis; 6. The supra-spinatus muscle; 7. The supra-scapular vessels and nerve; 8. The smooth concave surface of the bone (fossa supra-spinata).

Below the spine of the scapula portions of the trapezius, deltoid, and latissimus dorsi muscles overlap the scapular region, and partly conceal from view the intrinsic muscles of the infra-spinal fossa. These muscles are covered by an *aponeurotic expansion*, which is thin over the trapezius and latissimus dorsi muscles; more dense and strong where it covers that part of the deltoid which belongs to the region of the shoulder; and much stronger still, where it invests the infra-spinatus and teretes muscles; superiorly, it is attached to the lower edge of the spine of the scapula; posteriorly, it is connected with the tendinous expansion of the trapezius muscle, and the base of the scapula. From its deep surface, septa are detached, which pass in between the subjacent muscles, and contract firm adhesions to the bone; whilst, at the posterior edge of the deltoid muscle, it divides into two laminæ, between which that muscle is enclosed; the superficial layer covers the outer surface of the deltoid, and so becomes identified with the fascia of the arm; whilst the deeper layer, passing beneath the deltoid muscle, becomes continuous with the capsule of the scapulo-humeral articulation.

The *trapezius* and *latissimus dorsi muscles* overlap—the one, the posterior superior, the other, the inferior angle of the scapula. The trapezius is tendinous where it glides upwards and forwards over the smooth triangular surface situated behind the spine of the scapula. A bursa here intervenes between the bone and the flat tendinous expansion of the muscle. The latissimus dorsi, by its fleshy fibres, overlaps the inferior angle of the scapula. The direction of the muscle at this part of its course is nearly horizontal. As these fibres pass off the scapula, they are joined by those of its costal origin, and thence they all run upwards and forwards, presenting a twisted appearance to their insertion, which takes place by a narrow flat tendon into the bottom of the bicipital groove of the humerus. Both these muscles, from their peculiar relation to the scapula, serve to compress it against the thorax, and so to prevent its being unduly separated from the trunk in the varied and extensive movements which it enjoys.

A peculiar displacement of the scapula, the result of accident, has been described by Velpeau, who supposes it to depend on paralysis of the serratus-magnus from injury of the great posterior thoracic nerve (external respiratory, Ch. Bell), which is distributed to that muscle. The appearances observed in the case detailed by Velpeau were, remarkable projection backwards of the scapula, especially of its posterior border, and inability on the part of the patient to bring it in contact with the side of the thorax: cases corresponding in their general features to this description have been seen by almost every surgeon. In those which have occurred in the writer's experience, the projection of the posterior edge *and of the lower angle* of the scapula was very remarkable, and the movements of the upper extremity were greatly impeded. Mr. Adams has suggested, as a more plausible explanation of the deformity in these cases, that the lower angle of the scapula escapes from under the latissimus dorsi muscle; an accident which may occur from too great elevation and abduction of the upper extremity; and the more easily, as, in the majority of instances, either the muscle is not attached to the bone at all, or else it adheres to it by a few small fibres only.

The deltoid, trapezius, and latissimus dorsi muscles, where they overlap the scapular region, circumscribe a triangular space, in which may be seen part of the posterior edge of the scapula, with the attachment to it of the rhomboid muscle, and also a portion of the infra-spinatus and of the teres minor muscles.

By the removal of so much of these superficial muscles as encroach on the scapular region, and of the strong fascia already described, the deeper seated muscles of the infra-spinal fossa, viz. the infra-spinatus and the teres major and minor, are completely exposed.

The *infra-spinatus muscle* arises from the upper four-fifths of the dorsum of the scapula below its spine. The strong fascia of investment already described also furnishes an extensive surface of origin to its fibres; the muscle is triangular, the fibres all converging anteriorly to their common tendon, which, passing beneath the spine of the scapula and the acromion process, approximates closely to the tendon of the supra-spinatus muscle, and is inserted immediately beneath it, into the great tuberosity of the humerus.

The *teres minor muscle* seems to be little else than a fasciculus of the last described muscle, to which it is parallel, and along the lower edge of which it is placed: anteriorly, it is inserted by a separate tendon into the lowest portion of the great tuberosity of the humerus. The teres minor and infra-spinatus muscles might be regarded as different portions of one and the same muscle, not only from the similarity of their anatomical relations, but also from the identity of their physiological functions; both draw downwards and backwards the humerus, and produce the rotation outward of the arm at the shoulder joint. The teres minor is placed between the infra-spinatus superiorly and the teres major inferiorly, in close contact with the former, from which an aponeurotic septum and branches of blood-vessels alone separate it; whilst a very considerable space, containing the long head of the triceps, and some important nerves and vessels, intervenes between it and the teres major.

The *teres major* and the *teres minor* muscles arise close together from the lowest portion of the dorsum of the scapula. The teres major (the more superficial of the two at its origin) is attached to the rough surface on the outer aspect of the inferior angle of the scapula, whilst the teres minor arises more anteriorly, from a narrow but well-marked groove, situated just above the axillary margin of the bone. At their origin the teres minor is concealed by the teres major, but as they pass towards the humerus they gradually diverge, and are inserted on different aspects of the bone, and at different levels, so that the long head of the triceps firstly, and the neck of the humerus secondly, intervene between them. The teres minor is inserted on the outside of the humerus into its great tuberosity, below the insertion of the infra-spinatus muscle, whilst the teres major, in company with the latissimus dorsi, passes on the inner aspect of the humerus, and is inserted along with it into the bottom of the bicipital groove: at their insertion, the tendon of the teres major is posterior, and a little inferior to the tendon of the latissimus dorsi.

The teretes muscles, in diverging to the humerus, form with the upper part of that bone a triangular space, of which the base is at the humerus, and the apex at the inferior angle of the scapula. The scapular origin of the triceps extensor muscle in its vertical course down the arm, crosses this space, and divides it into compartments, a posterior triangular, and an anterior quadrilateral one, through both of which the axillary cavity communicates with the posterior region of the scapula and shoulder.

The *triangular compartment*, overlapped posteriorly by the deltoid muscle, is bounded, *above*, by the teres minor and axillary edge of the scapula; *below*, by the teres major. Its *base*, situated *externally*, is formed by the long head of the triceps; whilst its *apex*, directed *internally*, corresponds to the point of contact of the teretes muscles, where they arise together from the scapula. In this compartment is seen the posterior branch of the sub-scapular artery (*circumflexus scapulæ*, Sœmmering), forming here a curve, the convexity of which is directed downwards and backwards. The artery leaves this space by bending upwards and backwards, beneath the teres minor and infra-spinatus muscles. It thus arrives in the infra-spinal fossa, lies next the bone, and ramifying minutely anastomoses, superiorly with the descending branch of the suprascapular artery, and posteriorly with the termination of the posterior scapular artery. (*Vide* AXILLARY ARTERY.)

The *quadrilateral compartment* is bounded *above*, by the capsular ligament of the shoulder joint, by the prominence of the head of the humerus, and by the tendinous attachments of the teres minor and of the sub-scapularis muscles; *below*, by the teres major and latissimus dorsi; *externally*, by the neck of the humerus; whilst, *internally*, it is separated from the triangular compartment last described by the long head of the triceps muscle; it transmits, from within outwards, the circumflex nerve and *posterior circumflex artery*. This artery contributes to form the great scapular anastomosis; some of its branches ascending in the substance of the deltoid muscle, inosculate freely with the superior acromial branches of the infra-scapular artery, whilst others pass backwards and unite in the infra-spinal fossa, with branches of the subscapular and the posterior scapular arteries. The *circumflex nerve* is distributed almost exclusively to the deltoid muscle; but two collateral branches are detached from it, which are distributed in the scapular region; the first, a branch to the teres minor muscle; the second, a cutaneous filament, which escapes from beneath the posterior edge of the deltoid muscle, and is distributed to the integument.

The *posterior scapular artery*, although placed beyond the limits of the scapular region, may, nevertheless, be here described, as it is distributed chiefly to the parts contained within it. Under the name of "*transversalis colli*," this artery arises in the neck from the thyroid axis, near to, and sometimes by a common trunk with, the transversalis humeri; it sometimes comes from the sub-

clavian, external to the scaleni muscles,—an irregularity which is by no means uncommon. When derived from its more usual source, this branch runs transversely across the scalenus anticus muscle and the phrenic nerve, covered by the clavicular portion of the sterno-cleido-mastoid muscle: it then traverses the apex of the supra-clavicular triangle, lying above the level of the curve of the subclavian artery, and placed before or between the formative roots of the brachial plexus; passing still further outwards it gets under the trapezius muscle, and here gives off its ascending cervical branch; at the posterior superior angle of the scapula, the artery bends backwards, under cover of the levator anguli scapulæ; here it changes its direction, and inclining downwards, runs along the vertebral edge of the scapula. Its course may, therefore, be divided into two stages; the *first* extends from the origin of the artery to the superior angle of the scapula, and so far its direction is nearly horizontal, and it is properly designated the "arteria transversalis colli." In its *second stage*, the artery runs vertically, parallel to, and about an inch distant from, the vertebral margin of the bone. This portion of the artery, which alone should be termed "posterior scapular," is covered by the greater and the lesser rhomboid muscles, and by the trapezius. To these, and to the other muscles attached to the scapula, it furnishes numerous branches, and at the inferior angle of that bone, it anastomoses very freely with the posterior branch of the sub-scapular artery.

The structures which occupy the *infra-spinal fossa* may here be briefly recapitulated: *first* the integument and the sub-cutaneous layer of areolar tissue; *secondly*, the fleshy edges of the deltoid and the latissimus dorsi muscles, and the triangular tendinous expansion of the trapezius, covered by their respective portions of fascia: in the interval between these muscles, and partly covered by them, lie, *thirdly*, the infra-spinatus, the teres major, and the teres minor, muscles; these are contained in distinct sheaths, formed by their investing fascia, and the aponeurotic septa detached from its deep surface; *fourthly*, the anastomoses of branches from all the scapular arteries; *fifthly*, the bone (fossa infra-spinata).

Around the margins of the scapula there exists, as has thus been shown, a chain of large blood-vessels, which, by numerous branches, anastomose freely at the angles, and on the different aspects of the bone, forming a vascular circle of great interest to the surgeon; for by means of it the upper extremity is mainly supplied with blood, when the current through the subclavian is interrupted, at the distal side of the branches which spring from its first stage. At the acromial end of the scapula two series of anastomoses may be observed; the *first*, superficial to the acromion process, is formed by the union of the superior acromial branches of the supra-scapular artery with the ascending (inferior acromial) branches of the circumflex, and with the acromial thoracic divisions of the axillary artery.

Secondly; an anastomosis occurs beneath the acromion process and behind the glenoid cavity, between the supra- and the sub-scapular arteries.

Thirdly; at the posterior angle of the scapula, the supra- and the posterior scapular arteries anastomose, in the posterior part of the supra-spinous fossa.

Lastly; at the inferior angle, a free communication exists under cover of the infra-spinatus muscle, between the supra-, the posterior, and the sub-scapular branches, aided by the posterior circumflex.

Through all these channels the sub-clavian and the axillary trunks communicate with each other, and experience has shown that full reliance may be placed on the capability of this anastomosis to maintain the circulation in the upper extremity after a ligature has been placed on the subclavian artery in the second or third stage.

The *veins* of the scapular region merit no particular description; they are very numerous, and communicate freely with each other. They accurately follow the course of the arteries. Those which lie above the spine of the scapula form one or two trunks of considerable size, which accompany the supra-scapular artery, and unite with the subclavian vein, external to the scalenus muscle; those of the infra-spinal fossa constitute a very large trunk, the *sub-scapular vein*, which enters the axilla and joins the axillary vein, as it lies on the posterior wall of the axilla: the sub-scapular vein here forms an important anterior relation to its accompanying artery.

The *lymphatics* of the scapular region are arranged in two sets; the superficial which pass to the ganglia of the axilla, and a deep set which closely correspond to the course of the bloodvessels, and terminate, as do the venous trunks, in the supra-clavicular and in the axillary regions.

The scapular region participates in the remarkable mobility of the bone which supports it, but as its motions cannot be regarded independently of those of the shoulder joint, we refer to the article on that subject for their elucidation.

The *uses* of the scapula may be briefly stated as follows:—In the *first* place it connects the upper extremity to the trunk, and participates in, and is subservient to, many of the movements enjoyed by the upper extremity. *Secondly*, it furnishes, by its flat surface, a lateral protection to that portion of the thorax against which it is applied. *Thirdly*, it is concerned in the mechanism of respiration, furnishing processes and surfaces for the attachment of numerous muscles, which are capable of altering the capacity of the thorax. This latter function of the scapula is well illustrated by cases where the upper extremities are totally wanting, in which the muscles, passing from the scapula to the thorax are well-developed, and act with vigour in effecting the full expansion of the thorax.

This fact is mentioned on Sir Charles Bell's authority, from whom we also quote the following short passage:—"We would do well to remember this double office of the scapula and its muscles, that whilst it is the very foundation of the bones of the upper extremity, and never wanting in any animal that has the most remote resemblance to an arm, it is the centre and "*point d'appui*" of the muscles of respiration, and acts, in that capacity when there are no extremities at all.

Percussion and auscultation are constantly practised over the scapular region, the superficial position of the spine of the scapula causing it to furnish satisfactory results when percussed, whilst the nature of the respiratory sound, in the subjacent portions of the lung, may be easily learned by applying the stethoscope to the supra- or infra-spinal fossa.

The scapular region is sometimes the seat of *furuncular inflammation*, and of anthrax, which selects in general the posterior aspect of the body, where the sub-cutaneous areolar tissue is most dense, often shows a special preference for the scapular region. Here likewise practical surgeons are well aware that *chronic abscesses* ("absces froid") not unfrequently occur.

Collections of matter in this situation are generally unconnected with any other local disease, but at the same time indicate constitutional derangement, more or less profound. Chronic abscess in this locality is not always superficially seated; it may have for its site the loose areolar tissue beneath the scapula, which connects the sub-scapularis to the serratus magnus muscle. Here it may attain a great magnitude, and displace the scapula outwards to a considerable distance from the trunk.

Fractures of the body of the scapula are met with as the result of direct violence only, and occur less frequently than the slightness of the bone would lead one a priori to expect. The numerous muscles covering the bone, which form for it an elastic cushion, and its strong projecting spine, are sources of protection to which the scapula is indebted for its comparative immunity from this form of injury.

Ablation of large portions of the scapula, or even the complete removal of that bone with part of the clavicle, and the scapulo-humeral articulation, has been had recourse to in cases of extensive injury of the shoulder, as from gunshot wounds. (Larrey.)

In the Hôpital des Invalides at Paris may be still seen living examples of the success which sometimes attends even such severe mutilations; whilst the records of British surgery also furnish successful instances of the complete removal of the scapula, scapular end of the clavicle, and upper extremity, for tumours of great magnitude occupying the region of the shoulder, of which the cases by Mr. Fergusson and the late Mr. Liston are amongst the most remarkable.

(*B. Geo. M'Dowel.*)

SCROTUM. Latin, per metath. *a scortum*, i. e. *pellis*; κόρυκος, ὄσχεος, ὀχεὺς, Gr.; *der Hodensack*, Germ. Neither the English nor French language appears to have retained any word exclusively significant of this part of the body. In the former tongue, the Saxon word "cod," a husk, or shell, or bag, seems to have been originally applied to it in common with other tegumentary tissues; *e. g.* "peascods." Subsequently, however, the meaning of the word was extended, and from the containing tissues came to imply the contents. It is now obsolete, and the only term popularly retained in both languages is "*the purse*," "*les bourses*," either in allusion to the scrotum resembling a purse, or from its tegumentary nature (βύρσα, pellis).

The *scrotum* is the pouch or fold of integument in which the testicles are placed, where they occupy an external position. It is composed of skin and areolar tissue, and is plentifully supplied with vessels and nerves. It contains the testicles, their cremaster muscle, and serous membrane, together with their arteries, veins, nerves, and efferent duct, and a considerable length of the spermatic cord, which continues these into the abdominal cavity.

The *skin* of the scrotum is continuous above and in the middle line with that which covers the inferior or urethral surface of the penis, and on each side with that of the lower part of the belly, the inguinal region, and the inner side of the thigh; behind, it is continuous with the perineum. Its colour is darker than the neighbouring integument, and in the adult its surface is sparingly occupied with hair; in health it is rendered irregular by the presence of numerous rugæ or furrows, the larger of which take a transverse direction. The median line offers a prominence which extends backwards to the anus, and which, from its likeness to a suture, modern anatomists have named the raphe* (ῥαφή, sutura).

The *areolar tissue* of the scrotum is continuous with, or, in anatomical language, derived from, that of the perineal and inguinal regions. The more superficial or subcutaneous fascia, together with that deeper layer which is attached to Poupart's ligament and to the ramus of the pubes, converges towards the scrotum; the two layers uniting to ensheath the spermatic cord and testicle of each side in a cylindrical prolongation, the apposition of the two bags in the middle line forming a common partition, the *septum scroti*.

The texture of this covering of areolar tissue is peculiar, or even sui generis, and perhaps led to its receiving the appellation of the *dartos* (δάρτος, tunica). It is very delicate, and highly elastic, and is usually of a reddish or pink colour; but it is not unlikely that this phenomenon may be of post-mortem occurrence: and it has the additional peculiarity of being destitute of the fat which is

* Its proper Greek name is ὄῤῥος. The etymology of the word is unknown, but it is used by Aristophanes and Galen.

found in connection with this tissue in most parts of the body. Later researches have shown a still further difference, viz. the possession of another structure — the unstriped or organic muscular fibre — which is either not present in the subcutaneous textures of other regions, or is in far more sparing quantity. The contractility which is the function of these fibres is quite independent of the will, and is not only readily developed on the application of a direct stimulus, but is also producible by cold, and is associated with general tonicity of the system. And in opposite conditions of warmth or debility, a relaxation of these fibres effaces the rugæ which their contraction had previously produced.

The *vessels* of the scrotum are numerous, but of little surgical importance; they are derived from those of the thigh and perineum. The superior and inferior external pudic, from the femoral artery, terminate by sending many small twigs to the integuments of the penis and scrotum; while, posteriorly, the internal pudic of each side sends forwards a superficial perineal branch, which likewise ends in these tissues, by ramifying and anastomosing with the preceding. The accompanying veins have in all respects a corresponding distribution.

The *nerves* are chiefly the anterior terminations of those seen in the perineal space. Thus on each side is the inferior pudendal, which leaves the sacral plexus with the small sciatic nerve; while, nearer the median line, are the two superficial perineal nerves (external and internal perineal). The branches of these are very numerous, and are traceable to the front of the scrotum. The ilio-inguinal, a small branch from the higher part of the lumbar plexus, and which perforates the abdominal muscles, together with a part of the genito-crural nerve from the same source, terminate near the front of the scrotum, but extend very little on it.

For the anatomy of the contents of the scrotum, as well as its morbid appearances, the reader is referred to the article "TESTICLE," in which they will be included.

(*William Brinton.*)

SECRETION.—This term is usually employed to designate the process of *separation* of those matters from the nutritious fluids of the body, which are destined, not to be directly applied to the nutrition and renovation of its organised fabric, but (1) to be either at once removed as injurious to its welfare, or (2) to be employed for some ulterior purpose in the chemical or physical processes of the economy itself, or to exert some kind of action upon other beings. The term is often used, also, to designate the *products* thus separated.

The nature of this process of separation is essentially the same in all cases, whatever may be the destination of its products; and we shall consider it, therefore, in the first place, without any further reference to them, than may suffice to indicate the boundaries of the three groups under which we have arranged them. It is probable that in almost every act of secretion a double purpose is served, the blood being freed from some ingredient whose accumulation would be superfluous, if not injurious; and the fluid separated having some secondary purpose to answer. Thus, whilst biliary matter becomes a positive poison if it be retained in the blood, it serves an important purpose, when poured into the duodenum, in completing the digestive process, and in preparing the nutrient contents of the intestinal canal for absorption. So, again, the cutaneous exhalation not only removes the superfluous water of the blood, but is one of the chief means of regulating the temperature of the body; whilst the sebaceous matter, poured forth by the glandulæ of the skin, serves to lubricate its surface, at the same time that it relieves the blood of matter which, not being nutritive, is extraneous. Even the urine, which seems to be eliminated merely for the removal of noxious matters from the blood, is sometimes made to serve an additional purpose, its acridity, or its peculiarly offensive odour (increased under the influence of terror), frequently rendering it an effectual means of defence. On the other hand, the substances which are separated from the blood for the purpose of discharging some important office in the economy, usually, if not always, contain some substances whose retention in the blood would be injurious, and which are therefore advantageously got rid of through this channel. Thus the salivary, the gastric, and the pancreatic fluids all contain an animal principle nearly allied to albumen; but this principle seems to be in a state of change, or of incipient decomposition; and it would seem not improbable, that whilst this very condition renders the albuminous matter useful in promoting the solution of the aliment, it renders it unfit to be retained within the circulating current.

It is impossible, therefore, to divide the secreted products strictly, as some have attempted to do, into the *excrementitious* and the *recrementitious;* that is, into those which are purely excretory in their character, and those which are subservient to further uses in the economy; most, if not all of them, partaking more or less of both characters. Still we may group the secreting processes for practical purposes, according to the *predominance* of one or other of the objects enumerated above; those being arranged under the first division, in which the depuration of the blood is manifestly the chief end, any other being rendered subservient to this, as is the case pre-eminently with regard to the urine; those being classed under the second, in which the ulterior purpose of the separated fluid would seem to be the principal occasion of its production; and this second group being subdivided, according as this ulterior purpose is connected with the operations of the economy itself, as is that of the tears, the saliva, the gastric fluids, &c., or is destined to act upon some other, as is the case with the milk, the odorous secretions, &c.

Another classification has been proposed, of which the foundation is the degree of resemblance of the secreted products to the normal constituents of the blood; those being associated into one group, whose characteristic ingredients are altogether unlike those of the blood; and a second group being formed of those, whose elements seem nearly allied to those of the blood. This classification is practically almost the same with the preceding; for, as we shall hereafter see, all the cases in which the secreted products are very unlike the constituents of the blood, are those in which they are most directly and speedily removed from the body; whilst those in which they serve some ulterior purpose, are for the most part also those, whose elements differ least from the components of the blood.

The first group of these processes corresponds with that which has been elsewhere treated of under the head of Excretion; and the resultant products have been termed *excrementitious secretions*, or more briefly *excretions*, in contradistinction to the *recrementitious secretions*, which are the products destined for ulterior uses.

There is another group of processes, which corresponds so completely with the secreting operations in its general nature, that it is difficult to avoid placing it under one category with them; the more especially, as the instruments by which it is effected correspond with the organs of secretion in the most essential features of their structure. We refer to that elaborating agency, which is now generally believed to be exerted upon certain materials of the blood by the spleen, thymus, and thyroid glands, and suprarenal capsules (which are sometimes collectively termed vascular glands), and also by the glands of the absorbent system. The "vascular glands," as will presently appear, exactly correspond with ordinary glands in all that part of their structure by which they withdraw or eliminate certain matters from the blood; and they differ only in being unprovided with excretory ducts for the discharge of the product of their operation. These products, instead of being carried out of the body, are destined to be restored to the circulating current, apparently in a state of more complete adaptiveness to the wants of the nutritive function; in other words, these vascular glands are concerned in the assimilation of the materials that are destined to be converted into organised tissues, instead of being the instruments of the removal of the matters which result from the disintegration or decay of those tissues. And in regard to the entire absorbent system, with its glandulæ, reasons will be presently advanced for regarding it all as one great secretory apparatus, whose relations are essentially antagonistic to those of the excreting apparatus; the materials of its operation being derived from the external world, and its products being poured into the blood; and its purpose being to supply fresh pabulum to the circulating fluid, whose effete matters are being drawn off by the eliminating agency of other glands, whose products are carried back to the external world.

The line of demarcation between the functions of nutrition and secretion can scarcely be drawn with definiteness; so close is the affinity between the two sets of operations, both in their nature and in their purpose. For, as will presently appear, every act of true secretion is really a part of the nutritive process, the selection of the materials on which the secreting organ acts being effected by the development of certain groups of cells, which, during their short period of existence, form a part of the solid constituents of the body; so that, as was first pointed out by Professor Goodsir, the functions of nutrition and secretion are essentially the same in their nature. In regard to the objects of the two functions, moreover, there is not that difference which might at first sight appear; for although the *nisus* of the nutritive functions is directed towards the increase and maintenance of the solid fabric, and that of the secreting operations to the removal of certain fluids from the circulating current, the retention of which would be injurious, yet here again there is much common ground. For, as was first pointed out by Treviranus, "each single part of the body, in respect of its nutrition, stands to the whole body in the relation of an excreted substance;" in other words, every part of the body, by taking from the blood the peculiar substances which it needs for its own nutrition, does thereby act as an excretory organ, inasmuch as it removes from the blood that which, if retained in it, would be injurious to the nutrition of the rest of the body. Thus the phosphates which are deposited in our bones are as effectually excreted from the blood, and prevented from acting injuriously on the other tissues, as are those which are discharged in the urine.

The application of this idea has been thus felicitously extended by Mr. Paget*: — "The influence of this principle may be considered in a large class of outward growing tissues. The hair, in its constant growth, serves, over and above its local purposes, for the advantage of the whole body; in that, as it grows, it removes from the blood the bisulphide of proteine, and other constituents of its substance, which are thus excreted from the body. Now this excretive office appears, in some instances, to be the only one by which the hair serves the purpose of the individual; as, for example, in the fœtus. Thus, in the fœtus of the seal, and I believe of most other mammals, removed as they are from all those conditions against which hair protects, a perfect coat of hair is formed within the uterus, and very shortly after birth is shed, and replaced by another coat of wholly different colour, the growth of which had begun within the uterus. Surely, in these cases, it is only as an excretion, or chiefly as such, that this first growth of hair serves to the advantage of the

* Lectures on Nutrition, Hypertrophy, and Atrophy. London Medical Gazette, 1847.

individual. The *lanugo* of the human fœtus is an homologous production, and must, I think, similarly serve in its economy, by removing from the blood, as so much excreted matter, the materials of which it is composed.

"Now if this be reasonable, we may carry this principle to the apprehension of the true import of the hair, which exists in a kind of rudimental state on the general surface of our bodies, and to that of many other permanently rudimental organs, such as the mammary glands of the male and others. For these rudimental organs certainly do not serve, in a lower degree, the same purposes as are served by the homologous parts which are completely developed in other species, or in the other sex. To say they are useless, is contrary to all we know of the absolute perfection and all-pervading purpose of creation; to say they exist merely for the sake of conformity with a general type of structure, is surely unphilosophical; for the law of unity of organic types is, in larger instances, not observed, except when its observance contributes to the advantage of the individual. No; all these rudimental organs must, as they grow, be excretions serving a definite purpose in the economy by removing their appropriate materials from the blood, and leaving it fitter for the nutrition of other parts, or adjusting the balance which might else be disturbed by the formation of some other part. Thus they minister to the self-interest of the individual; while, as if for the sake of wonder, beauty, and perfect order, they are conformed with the great law of unity of organic types, and concur with the universal plan observed in the construction of organic beings."

We cannot have a better example of the close affinity between the functions of nutrition and secretion, in regard alike to their essential nature and to their purpose, than that which is afforded by the structure, growth, and offices of the adipose tissue. Fat, wherever it exists, whether in large isolated masses, or dispersed through areolar tissue, is made up of an aggregation of minute cells, whose peculiar province it is to draw into themselves the superfluous oleaginous matter of the blood, as a part of the history of their own development. Since they form constituent parts of the organism, and may possess as great a duration as that of any other of the elements of the soft tissues of the body, the growth of fat cells is commonly regarded as an act of nutrition. But it may also be considered as an act of secretion; for it is the means of separating from the blood a product which is not destined to undergo any further organisation, and whose accumulation in the circulating fluid, beyond a very small and limited amount, would be positively noxious. This very same act of elimination of fatty matter, when performed by the cells of the liver, or of the sebaceous follicles of the skin, or (abnormally) by those of the kidney or of the intestinal glandulæ, is recognised as forming part of the function of excretion, the difference being simply in the position and relations of the secreting cells. For whilst those of the glands are placed upon or near the free surfaces of follicles or ducts, and are destined from the first to a speedy exuviation, those of fat are woven up with areolar fibres and membranes, and form solid masses of tissue. A distinction might be drawn, on the ground that the contents of the fat cells are destined to be again taken into the circulation; whilst those of glandular cells, having been once eliminated from the blood, are never to return to it. But this would not hold good; for the fat cells appear to have an indefinite duration, the reception of their contents into the circulating current seeming entirely to depend upon the demand for these in the blood*; and there is now sufficient evidence that a considerable part of the bile that has been secreted and poured into the intestinal canal is destined for re-absorption. And if we admit that the spleen, thymus and thyroid bodies, and supra-renal capsules, are to be regarded as possessing a *glandular* character, although the products of their elaboration are destined to be received back again into the current of the circulation, it is difficult to find a reason for the exclusion of a mass of adipose tissue from the same category.

Of the organs of secretion. — In order that we may duly understand the real nature of the secreting process, as elucidated by recent discoveries, it is requisite that we should examine into the nature of the instruments by which it is effected. There can scarcely be a more beautiful illustration of the doctrine that physiology is as capable as any other science of being reduced to general principles, and that these principles must, if valid, be of *universal* operation, than the fact that the process of secretion — common as it is in all its essential features to the animal and vegetable kingdoms — is every where performed by the same agency, namely, the development of simple *cells*, each possessing its own independent vitality; these bodies forming the really operative part of every secreting

* May not this re-entrance be governed simply by physical laws? There can be no question that the chief purpose of fat is to serve as a store of combustible matter, for the maintenance of the heat of the body, when there is a deficiency of materials in the blood. A certain proportion of fatty matter (from 4 to 6 parts in 1000) seems normally to exist in the blood; and this is usually renewed from the food as rapidly as it is eliminated by the respiratory process, or by the nutrition of the nervous tissue. But if the supply be withheld, a diminution of the quantity of oleaginous matter in the circulating current must rapidly take place; and it is then that we find the contents of the fat-cells reabsorbed into the blood. It has been shown by Matteucci that oleaginous matter will pass through a membranous septum towards a slightly alkaline fluid, such as the blood; and it does not seem difficult to understand, therefore, how the fat-cells should give up a portion of their contents when the alkalinity of the blood is no longer neutralised by the fatty matter which it normally contains, and how just that amount should pass back again, which is necessary to keep up the due proportion of fatty matter in the blood, and no more.

organ, however complex its structure may be. The progress of comparative anatomy has shown that neither the form nor the internal arrangement of the parts of a gland could have any essential connection with the nature of its product (see GLAND); since even those glands (the liver and the kidney, for example) in which there is the greatest complexity of structure, make their first appearance at the lower end of the animal series, as in the early embryo of the very highest, in the simplest possible form. Still something was wanting to prove that the structural elements immediately concerned are in all instances the same; and there seemed no analogy whatever between the secreting *membrane* of the animal and the secreting *cell* of the plant. The doctrine was first propounded by Purkinje * and Schwann †, adopted and extended by Henle ‡, and fully confirmed by the researches of Goodsir § and Bowman ‖, that the true process of *secretion* — under whatever form it may present itself — is always performed by the intervention of cells; which, as part of their own regular vital actions, select and withdraw certain ingredients from the nutritive fluids, and afterwards set them free again, generally by the rupture or dissolution of the cell-wall, but sometimes perhaps by a simple act of transudation. For the proper comprehension of this doctrine in all its generality, it is necessary to give some attention to the history of cell-development, as manifested in the simplest forms of organic existence; those cryptogamic plants, namely, in which every cell is a distinct and independent individual.

The earliest condition of such a cell is a minute molecule, which cannot be discerned except under a considerable magnifying power, and in which even the highest amplification fails to exhibit any distinction of parts. When placed under circumstances favourable to its development, — namely, when supplied with the materials of its nutrition, and stimulated by the requisite degree of warmth, — this germ increases in size; and a distinction becomes apparent between its transparent exterior and its coloured interior. Thus we have the first indication between the *cell-wall* and the *cell-cavity*. As the enlargement proceeds, the distinction becomes more obvious; the cell-wall is seen to be of extreme tenuity and perfectly transparent, and to be homogeneous in its texture, whilst the contents of the cavity are distinguishable in the Algæ by their colour, which is green in the *Chlorococci*, and bright red in the *Hæmatococci;* but in the simple fungi, such as the *Torula cerevisii*, or yeast-plant, they are colourless. The contents of the cell-cavity have no relation whatever to the material of the cell-wall. Of this we have a remarkable example in the cases just cited; for whilst the red and green coloured products of the Algæ are probably nearly related to each other and to the chlorophyll of higher plants, being simple ternary compounds of water and carbon, the cell-contents of the yeast-plant are closely allied to the protein compounds; and yet the cell-walls in both instances are composed of the same material, cellulose. It is evident, then, that the inherent powers of the cell are not confined to the application of nutrient materials to the extension of its own walls, and the consequent enlargement of its cavity; but that they are exercised also in selecting from (and it may be in combining or modifying) the same materials, in order to fill this cavity with a certain product, which may be altogether different in its constitution and its properties from that of which its wall is composed. This latter process is as essential to our idea of a living cell, as is the growth of its wall; and must never be left out of view when the history of cell-development is being considered.

The nature of the compound thus stored up in the interior of a cell depends in part upon the original inherent endowments of the cell itself, derived from its germ; and, in part, upon the character of the nutriment supplied to it. Thus we find that the simple Algæ will grow wherever they can obtain, from the air and moisture around, the elements of their cell-walls and of their cell-contents; which elements they have themselves the power of combining into those peculiar compounds, of which analysis shows that they are composed. But out of the very same materials, and under circumstances to all appearance identical, the Chlorococcus manufactures a green product, and the Hæmatococcus a red one. On the other hand the yeast-plant, like the fungi in general, will only grow where it meets with an azotised compound already formed; and from this it elaborates the product which occupies its cell-cavity, its cell-wall being apparently formed by the same process as that of the simplest Algæ. It could no more vegetate, as they do, upon cold damp surfaces, than they could develop themselves in a solution of fermentible matter secluded from the light.

A similar variety of function is seen amongst the cells, whose aggregation makes up the structure of any one of the higher plants, and which are all the descendants of the single cell which constituted its original germ. Thus we have in the green cells of the leaves the representatives of the simple Chlorococci; these, under the influence of solar light, combining the carbon which they derive from the atmosphere, or from the soil, with the water transmitted from the roots, and elaborating these elements into a variety of new products, amongst which chlorophyll and cellulose are still prominent; but also operating upon the azote which they draw from the atmosphere

* Isis, 1838, No. 7.

† Froriep's Notizen, Feb. 1838.

‡ Müller's Archiv. 1838, p. 104—108; 1839, p. 45.

§ Trans. of Royal Society of Edinburgh, 1842.

‖ Art. MUCOUS MEMBRANE; and Phil. Trans. 1842, "On the Structure and Uses of the Malpighian Bodies of the Kidney."

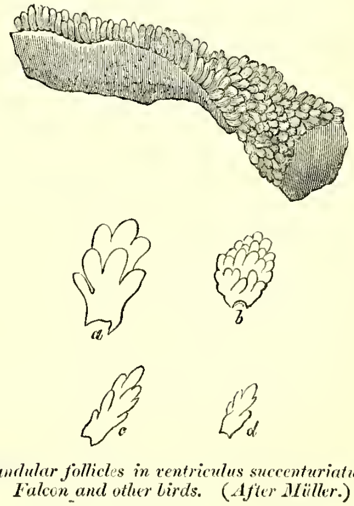
or from the soil, and combining this with the other three elements into quaternary compounds, that seem destined rather for the nutrition of animals than for any special purpose in the economy of the plant itself. The contents of the cells of the leaves are thus of a very complex nature; their life not beginning and ending with themselves, as is the case with that of the independent organisms, which in other respects they resemble; but having relations to the rest of the structure, for which, in fact, it is their function to prepare the *pabulum*. For the elaborated sap or nutritious fluid, which is the product of their agency, is transmitted through the entire fabric, and furnishes each portion with the materials of its development and extension, which in every instance is effected by an act of cell-growth. All parts select from it the same substance for the formation of the cell-walls, but the cell-contents are different in every organ and variety of tissue. Thus we find one set of cells drawing in starch, another fixed oil, another resin, another volatile oil, another colouring matter, another sclerogen, another protein compounds, and so on; and this with the greatest uniformity and regularity. We may frequently see that even contiguous, and in other respects similar, cells, in the same organ, either select from the common pabulum a different compound, or exercise upon the same compound a different influence. Thus we observe in the parti-coloured petal of a hearts-ease or tulip, certain stripes or patches of different hues, which, when examined with the microscope, are found to consist of cells that differ from each other only in the colour of their contents. A precisely similar phenomenon is presented by the epidermic cells, which constitute the *scales* of the wings of Lepidoptera.

In all these cases, however, the products which are separated from the circulating fluids are stored up within the component cells of the fabric, instead of being cast forth from it; and although the term secretion is commonly applied to the process, yet it would be just as correct to regard it as part of the function of nutrition. It is, in fact, exactly on the same footing with the production of fat in animals.

The absence of necessity for any other form of excretion in plants, than that which is carried on through the respiratory process, may be accounted for without much difficulty. A large proportion of the vegetable fabric is (from the nature of its chemical constitution) but little prone to decomposition, and possesses a character so permanent, that it may remain almost unchanged for an indefinite time; and those parts which are of softer texture and more actively employed in the vital processes, and which are therefore more prone to decay, are periodically thrown off and renewed. In animals, on the other hand, all the softer tissues have a strong tendency to disintegration, in virtue of their peculiar composition; and in some of them a destructive chemical change seems to be the very condition of their functional activity. For the maintenance of their vital energy, therefore, there is needed not merely a constant supply of new material, but a continual removal of the effete particles. On this last operation, indeed, the continuance of the vital activity of animals is more closely and immediately dependent, than it is upon the supply of aliment; for whilst the latter may be interrupted for a period of considerable duration without producing more than debility, the former cannot be checked for many hours (in the warm-blooded animals at least) without a fatal result. Indeed, if we consider respiration as one of the excreting processes (which it undoubtedly is in a broad and philosophical acceptation of the latter term), we must say that the liberation of effete particles may not be suspended for more than a few minutes without death ensuing.

Turning our attention, then, in the first instance, to the excretory organs of animals, we may define them to be groups of cells, placed on the free surface of a membrane, which is directly continuous with that of the exterior of the body, whilst its attached surface is in relation to the blood-vessels, &c. of the interior; so that these cells, having grown and developed themselves at the expense of the materials supplied by the blood, are either cast off entire and conveyed away, or give up their contents by the rupture or deliquescence of their walls; the products which they have selected or eliminated being thus, in either case, entirely got rid of from the interior of the fabric. The disposition of the membrane on which the cells lie, whether it be spread out on a plane surface, depressed into short rounded follicles, or extended into long and convoluted tubes, is a matter of secondary consequence; nor is it of more importance whether the follicles be isolated, and discharge their contents by separate outlets, as those of the skin or mucous membrane (*fig.* 307.), or whether they are aggregated in clusters, and

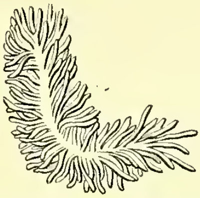
Fig. 307. (*Fig.* 209. Vol. II.)



Glandular follicles in ventriculus succenturiatus of Falcon and other birds. (*After Müller.*)

open into a common channel, like those of the liver of the lobster or cray-fish (*fig.* 308.);

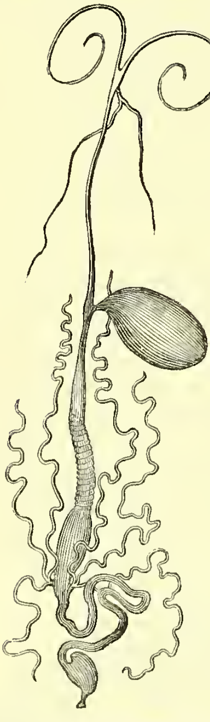
Fig. 308. (*Fig.* 214. Vol. II.)



Lobule of the liver of Astacus fluviatilis. (*Müller.*)

nor, again, whether the tubes are few and of great length, lying loose in the cavity of the body, and passing from one end of it to the other, like the biliary vessels of insects

Fig. 309. (*Fig.* 431. Vol. II.)



Alimentary canal of Pontia brassica.

(*fig.* 309.); or whether they are very numerous, of less proportional length, and aggregated in a compact mass, as in the kidney of the higher animals.

In all instances, then, the excretory organ essentially consists of a limitary membrane, which forms part of the integument of the body, or of one of its involutions; and of cells covering the free surface of that membrane, and, consequently, in direct relation with the external surface. Thus we have the limitary membrane of the true skin, and of the mucous membrane of the alimentary canal which is directly continuous with it, sunk into follicular depressions; and the free surfaces of these are lined with cells, the layers of which are continuous with those of the epidermis and of the gastro-intestinal epithelium respectively. (See Mucous Membrane.) We trace inwards another extension of the same membrane along the genito-urinary passages, up to the kidneys, where it forms the walls of the tubuli uriniferi; and there, too, its free surface is covered with an epithelial layer of cells, which is the efficient instrument of the selection of the constituents of the urinary fluid, and which, when exuviated, is conveyed along the urinary passages to the exterior of the body. So, too, the hepatic cells, by which the biliary matter is eliminated from the blood, are brought into direct continuity with those of the external surface, through the hepatic ducts and gastro-intestinal mucous membrane.

The case is not different, in any essential respect, with regard to the organs by which the recrementitious secretions are formed. Thus the lachrymal, salivary, pancreatic, and mammary glands are in like manner composed of a continuation of the limitary membrane of the true skin, or of the mucous membrane lining the alimentary canal, involuted into tubes and follicles, the free surfaces of which are covered with epithelial cells. These cells, drawing into themselves certain constituents of the blood, are cast off when they have completed their full development; and their contents, set free by the disintegration of the cell-walls, are carried off by the ducts, which collect them from different portions of the glandular structure, and deposit them in the situation where the purposes of the secreted product are to be answered.

If we attentively consider the character of what is commonly designated as the *absorbent* system, we shall see that this, too, may be regarded as a glandular apparatus; possessing, as it does, the essential characters of a gland in regard to its structure, and being analogous to the true glands in its mode of performing its function, and the difference of its purpose in the general economy being accordant with the difference of its anatomical relation. Putting out of view for the time the absorbent glands, or ganglia, we find the absorbent system to consist of two series of long tubuli, one set extended through almost the entire body, whilst the other is distributed upon the intestinal canal. These tubes appear to commence either in cæcal origins or in loops; they coalesce with each other; and at last discharge themselves into a common receptacle, just as do the tubuli of the kidney. That their origins should be widely scattered, instead of being bound together in one compact mass, is a fact of no physiological importance; having reference only to the remoteness of the sources, whence are derived the materials on which the particular agency of this apparatus is exerted. These materials are of two kinds; for they consist in part of the crude materials selected by the lacteal division of the system from the contents of the alimentary tube, over whose walls the origins of the

lacteals are dispersed; and in part of substances taken up by the lymphatic or interstitial division, and probably consisting chiefly of particles which are set free by the continual disintegration of the living structure, but which, not being yet decomposed, are capable of being again employed for the purposes of nutrition. The materials derived from these sources appear to require a considerable preparation or elaboration, before they are fit to be introduced into the current of the circulation; and this elaboration is effected by an agency of precisely the same nature with that which is concerned in the removal of various products of secretion from the blood; for the tubuli of the absorbent system, like those of the kidney or the testis, are lined by epithelial cells, and their duty seems to be altogether analogous. The alterations which the absorbed matters undergo during their passage along this system of tubes, and the evidence that these alterations are in great part due to the elaborating action of cells, having been heretofore considered (*see* NUTRITION), need not be again dwelt on; but a few words may be added respecting the structure and functions of the glandulæ or ganglia, with which the absorbent vessels of man and the mammalia are copiously furnished. These bodies are composed of lacteal or lymphatic trunks, convoluted into knots, and distended into cavities of variable form and size, which are known as the "cells" of these glands. Amongst these cells there is a copious plexus of blood-vessels, but there is no direct communication between their cavities. According to Prof. Goodsir *, the epithelium which lines the absorbent vessel undergoes a marked change where the vessel enters a gland, and becomes more like that of the proper glandular follicles in its character. Instead of being flat and scale-like, and forming a single layer in close apposition with the basement membrane (as it does in the lacteal tubes before they enter the gland, and after they have emerged from it), we find it composed, within the gland, of numerous layers of spherical nucleated cells, of which the superficial ones are easily detached, and which appear to be identical with the cells that are found floating in the chyle and lymph, especially after their passage through these bodies. The absorbent glands may be regarded, therefore, as concentrating within themselves that agency, to which the whole system of tubuli is more or less subservient. Such an idea is strictly accordant with the facts of comparative anatomy; for in reptiles, in which there are no glands, the tubuli or vessels are enormously lengthened by the convolutions which they present along their course, as if to furnish a sufficient extent of epithelial surface.

There is strong reason for regarding the spleen, the thymus and thyroid glands, and the supra-renal capsules, as parts of the same assimilative apparatus, their office apparently being, to withdraw certain crude matters from the blood, to submit these to an elaborating action whereby they shall be rendered more fit for the nutrition of the tissues, and then to restore them to the circulating current. The details of the structure of these organs will be found under their respective names; and it will be sufficient to state here, that they all show an essential correspondence with the true and recognised glands in every respect but this, that they have no efferent ducts. Each of them may be described as consisting essentially of a number of vesicles, which are either closed and isolated, or open into a common reservoir, which is itself closed; the vesicles in either case are lined with epithelial cells.* Around these, as around the follicles or tubuli of the true glands, blood-vessels are copiously distributed; and the elimination of products from the blood appears to be effected by their agency, precisely as if these products were destined to be cast out of the body. The mode in which they are taken back into the circulation, after they have been subjected to the elaborating process, is not very clear; both blood-vessels and absorbents have been supposed to participate in the operation; and this idea may not be regarded as improbable, when the large size and number of the lymphatics distributed to these organs is considered.

Having thus taken a general survey of the principal varieties of secretory structure, and of the chief aspects under which the secreting function presents itself, we shall pass on to a more particular consideration of the mode in which this operation is performed, and of the instruments by which it is effected. For this purpose it will be preferable to select a particular gland, and to examine the minutiæ of its structure in the most diverse forms and conditions under which it presents itself; and there is none which suits our purpose so well as the liver, which is the gland of most universal existence throughout the whole animal series, and which presents almost every leading variety that is found in the whole series of glandular structures. And we gladly avail ourselves of the opportunity thus afforded, of bringing the account already given of that gland (*see* LIVER) into conformity with the increased knowledge of its structure that has been since acquired.

There are few animals possessed of a distinct digestive cavity, in which some traces of a biliary apparatus (recognisable by the colour of the secretion) may not be distinguished. Thus in the *Hydra*, some of the cells that form the lining of the stomach contain a brownish-yellow matter, strongly resembling bile, which is probably poured into the cavity on the rupture of the cells. In the walls of the stomach of the *Actinia*, Dr. Thomas Williams has described sulci formed by duplicatures of the lining membrane, in which are lodged a set of cells of glandular appearance, some

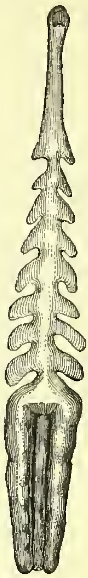
* Anatomical and Pathological Observation p. 46.

* See Prof. Ecker, in Annales des Sciences Naturelles, Zoologie, Aout, 1847.

of them containing scarlet-red, and others bright yellow granules; the latter are regarded by Dr. W., and probably with justice, as the diffused rudiments of a liver.* In the *Bowerbankia densa*, and in other *Bryozoa*, very distinct spots may be seen in the parietes of the stomach, which seem to be composed of clusters of biliary cells contained within follicles; and during digestion, the contents of the stomach are seen to be tinged with a rich yellow-brown hue, derived from the matter discharged from these follicles.† In the *Asterias* the digestive cavity is surrounded by a more complicated glandular apparatus, but it seems difficult to determine the precise portion of this which discharges the function of a liver. The central stomach is furnished with a pair of glandular appendages, each composed of a cluster of follicles, which open into its fundus; and these, from their dull yellow colour, have been thought to be a liver. Dr. Williams states, however (loc. cit.), that their ultimate structure does not sanction that idea, the terminal vesicles abounding in a white elastic tissue, in the meshes of which are entangled a number of small, compact, and granular cells, which are by no means hepatic in their aspect. He is disposed to agree with Dr. Grant, who hints that this organ may be a rudimentary pancreas; we should, ourselves, regard it as more probably a salivary gland, its secretion being apparently mingled with the food immediately upon the ingestion of the latter. In the walls of this central stomach, proper gastric follicles have been detected by Dr. Williams; and he regards in the light of an hepatic organ the dilated culs-de-sac, filled with large glandular cells, which are disposed in great numbers along the ramifying cæcal prolongations of the central stomach that are extended into the rays.

In the lower groups of the Articulated series, we meet with a diffused form of the biliary apparatus, not unlike that which has been just described in the lower Radiata. Thus in the *Earthworm*, the large annulated alimentary canal is completely encased in a flocculent external coating, which, when examined with the microscope, is found to consist of a mass of minute flask-shaped follicles, held by tubular peduncles, several of which coalesce to form the excretory canals for the discharge of the secretion into the digestive cavity. These follicles are composed of a membrane of extreme tenuity, and their interior is filled with cells containing granular matter and oil globules, which are the constituents of the hepatic secretion. In the *Leech* and some other *Annelida*, the alimentary canal is furnished with large sacculated appendages; and in the walls of these, as well as of the central canal, the biliary cells are closely disposed. These cells, according to Dr. Williams, are not included within follicles, as in the earthworm; the absence of cæcal multiplications of the stomach in the latter being compensated by a concentration of parts in

Fig. 310. (*Fig.* 69. Vol. I.)



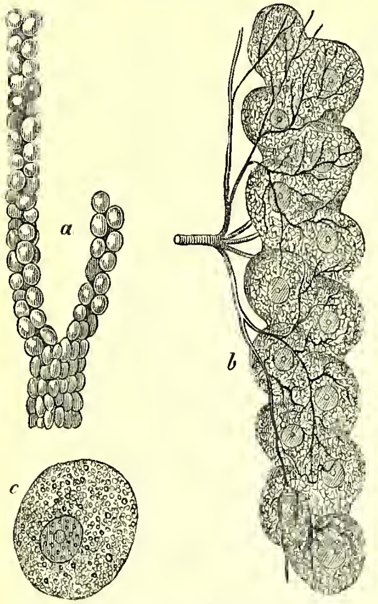
Alimentary canal of Leech, with cæcal prolongations.

the biliary system. In the *Myrapoda*, there is a decided advance from this diffused form of hepatic structure, towards that more concentrated and isolated condition, in which we find the liver of *Insects*. The general distribution of the biliary organs in this class has already been described. (See Insects, Vol. II. p. 974.) They consist of a number of distinct filiform tubes, usually of a yellowish-brown colour, placed in close apposition to the sides of the alimentary canal, and opening into it near the pyloric extremity of the stomach, usually by separate orifices, but sometimes after the junction of two or more with each other, to form short common trunks. Their number varies considerably; the fewest, namely four, existing in the *Diptera*, six being found in the *Lepidoptera*, and many more in the *Orthoptera* and *Hymenoptera*. When few in number, they are very long, sometimes three or four times the length of the alimentary canal, and are tortuous and convoluted; when numerous, they are proportionally short, and are more delicate in structure. In many larvæ, they are furnished with lateral cæca, but these almost always disappear as the insect approaches the imago state. The following is the description recently given of the minute structure of the biliary tubuli, by a well qualified observer:— "When more intimately examined, these tubes are found to consist of a delicate tube of clear, transparent, amorphous basement membrane, the inner surface of which is covered with secreting cells. From the thinness of the tube, the cells often project, so as to give it a granulated appearance when

* Guy's Hospital Reports, 1846, p. 280.
† Dr. A. Farre, in Phil. Trans. 1837.

viewed by the naked eye, as in the flesh-fly, *Musca carnaria* (*fig.* 311. *a*, *b*); and generally

Fig. 311.



Biliary Organs of Musca carnaria.

a, portion of a trunk and two branches of one of the biliary tubes of the flesh-fly, viewed by reflected light, and magnified eight diameters; *b*, portion of a biliary tube of the flesh-fly highly magnified, exhibiting the arrangement of the secreting cells, and the mode of distribution of the tracheæ; *c*, a secreting cell from the liver of the flesh-fly, very highly magnified. (*After Leidy.*)

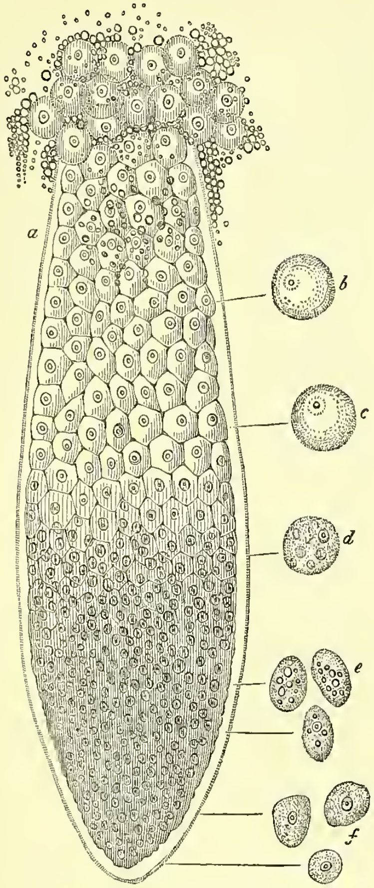
towards the free extremities the sides of the tubes are so irregular, that they appear as if merely folded upon the secreting cells to keep them together. The secreting cells are round, oval, or nearly cylindrical from elongation. Their average measurement is about ·09 millim. The contents are white, yellowish, or brownish, and consist of a finely granular matter, numerous fine oil globules, a granular nucleus, and a transparent nucleolus. The cells in the extremity of the tubes are not more than half the size of those a little further on (or nearer the termination), and contain less granular matter and no oil globules, so that they are more distinct, and the nucleus more apparent. Upon advancing a very little, the cells are found to be of an increased size, and full of granular matter, so as considerably to obscure the nucleus from view. A little further, we find the addition of fine oil globules, readily distinguishable by their thick, black outline when viewed in a certain focus. Sometimes the cells become so filled with oil, as to be distended with it, rendering the granular matter and nucleus so transparent as totally to destroy all appearance of the former, and the latter only is to be perceived in faint outline. Such a state I have frequently observed in *Dermestes*, *Ateuchus*, &c. The nucleus (*fig.* 311. *c*) is generally central, globular, and pretty uniform in size in the same species, averaging in measurement about ·025 millim. The nucleolus is always transparent, and measures about ·006 millim. The central passage of the tubes, or separation of the cells in the middle line, is usually found filled with fine granules, and a great amount of oil globules. The biliary tubes of insects are bathed in blood, or the nutritive fluid, and the respiratory tracheæ are distributed to them with extreme minuteness, but are separated from the secreting cells by the intervention of the basement membrane."* According to Dr. T. Williams (op. cit.), some at least of the large cells which give the sacculated appearance to a biliary tubulus are really parent cells, filled with a second generation of hepatic cells; they are, therefore, analogous to follicles, save that they have no proper outlet, for we shall hereafter see that the follicle in its earliest condition is probably nothing else than a parent cell. From the above description, it would appear that the hepatic cells originate towards the upper or cæcal end of the tubulus, that they are gradually being pushed onwards towards the outlet by the growth of new generations behind them; and that, as they thus advance, they acquire an increase in size by their own inherent powers of development, at the same time drawing into themselves the peculiar matters which they are destined to eliminate from the circulating fluids. The cells, having attained their full growth, and completed their term of life, give up their contents by the rupture or deliquescence of their walls, and these pass down the central cavity of the tube, to be discharged into the alimentary canal.

In the higher *Crustacea* we find a condition of biliary structure much more closely allied to that of Mollusca than to that of Insects; the liver being a pair of massive lobulated bodies, each of them made up by the aggregation of numerous cæcal follicles, from every one of which passes off a narrow duct, to join a trunk that is common to all the vesicles on one side. "In structure," says Dr. Leidy (loc. cit.), "the cæca resemble the tubes of insects, being composed of a sac of basement membrane, within which, originating from the inner surface, are numerous secreting cells (*fig.* 312. *a*). The cells are more or less polygonal in form, from mutual pressure. At the bottom of the cæca the cells are small, with an average diameter of 02 millim., and contain a finely granular matter of yellowish hue, with a granular nucleus, and a transparent nucleolus. As we proceed from the bottom upwards, the cells (*f*, *e*, *d*, *c*, *b*) are found to increase in size, and to obtain a gradual addition of oil globules, until beyond the middle of the tube, where they are found filled with oil, so as to have the appearance of ordinary fat cells, and have a diameter averaging ·06 millim. From this arrangement of the cells, when a cæcum is viewed beneath the microscope, its lower half appears filled

* Leidy, in American Journal of the Medical Sciences for Jan. 1848.

with a finely granular matter, intermingled with nucleolo-nucleated bodies, and the an-

Fig. 312.



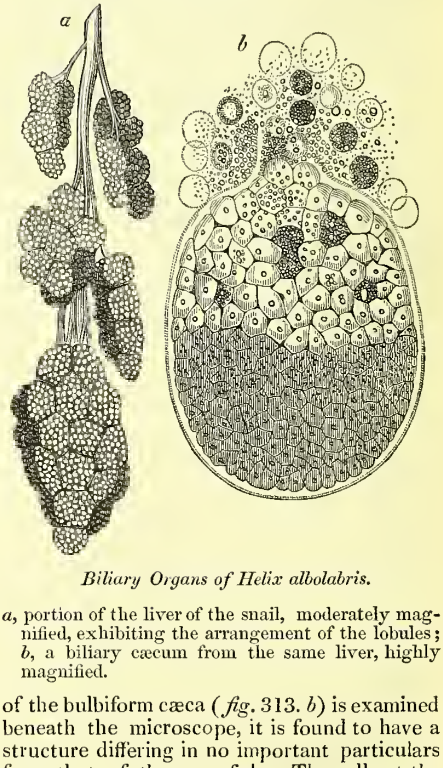
Biliary Organs of Artacus affinis.

a, cæcum of the liver of Cray-fish, with its contained cells; *b*, *c*, *d*, *e*, *f* exhibit the progressive changes of the cells, as they advance from the bottom of the tube. (*After Leidy.*)

terior half with a mass of fat cells, the nucleus hardly visible, from the property of oil rendering organic tissues more or less transparent. The central cavity of the cæca is filled with fat globules, and a finely granular matter corresponding to that in the interior of the cells." In some of the lower forms of Crustacea, the liver is reduced to the simple condition which it presents in insects; and there is one very curious group, that of *Pycnogonidæ*, in which the biliary apparatus is as much diffused as in the Radiata. In these animals, the stomach sends cæcal prolongations into the legs, and these extend nearly to their terminal claws. The walls, both of the central stomach and of its tubular extensions, are studded with brownish-yellow cells; but beyond this there is no rudiment of any organ for the secretion of bile.

In the *Molluscous* animals, the general structure of the liver closely corresponds with that which has just been described in the higher Crustacea. Among the *Compound Tunicata*, however, to which the Bryozoa are so nearly related that many naturalists associate them together in one group, the structure of the liver is the same as that of Bowerbankia; the hepatic follicles being isolated from each other, and lodged in the walls of the stomach, into the cavity of which they pour their secretion by separate orifices. In the *Solitary Ascidians*, the hepatic follicles are more developed, and cluster round the exterior of the stomach, so as to give it a shaggy appearance, very much as in the earthworm. In the *Conchifera*, the liver presents itself as a distinct organ, composed of numerous lobules; each of these is made up of a cluster of tubes, terminating at one extremity in flask-shaped follicles, whilst at the other they coalesce into a few larger trunks, which discharge themselves into the digestive cavity. The follicles are filled with cells containing the biliary secretion. The structure is nearly the same in the *Gasteropoda*; the ducts of the several lobules coalescing, so as to form two main trunks, by which the secretion is poured into the duodenum. The following is Dr. Leidy's account of the minute structure of the liver of the snail; a portion of which, moderately enlarged, and showing the arrangement of the lobules, is shown in *fig.* 313. *a.* "When one

Fig. 313.



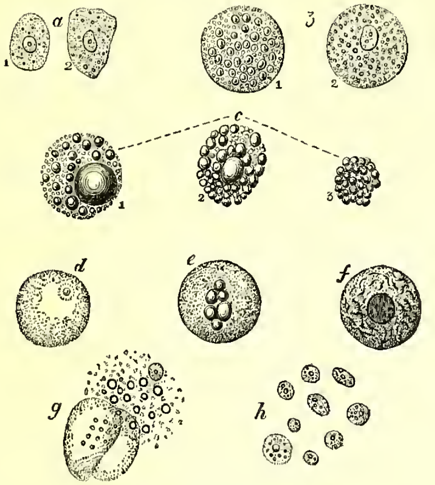
Biliary Organs of Helix albolabris.

a, portion of the liver of the snail, moderately magnified, exhibiting the arrangement of the lobules; *b*, a biliary cæcum from the same liver, highly magnified.

of the bulbiform cæca (*fig.* 313. *b*) is examined beneath the microscope, it is found to have a structure differing in no important particulars from that of the cray-fish. The cells at the bottom of the sac (*fig.* 314. *a*, 1, 2) average

·02 millim. in diameter; those towards the other extremity about ·04 millim. Some of

Fig. 314.



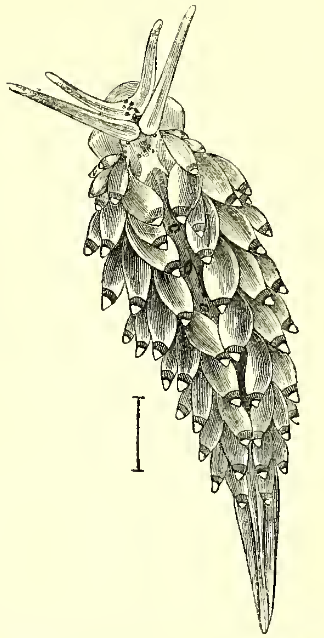
Hepatic cells of Helix albolabris.

a, 1, 2, two cells from the bottom of the cæcum; *b*, 1, 2, two cells more advanced, containing numerous oil globules; *c*, 1, 2, 3, three cells, containing larger oil globules; *d*, a cell distended with oil; *e*, a cell containing nothing but six deep yellow consistent oil globules; *f*, a cell containing a hard yellow mass of fat; *g*, a cell rupturing, and its contents escaping; *h*, nuclei of hepatic cells, highly magnified.

the fully ripe cells (*b*, 1, 2) are filled with innumerable minute globules of oil, hardly distinguishable from the granular matter; others (*c*, 1, 2, 3) with globules of a larger size; some are found with from one to ten or more large, deep yellow, oil globules in the centre; a few (*f*) with a hard or crystallised mass of fat in the centre; and many (*d*) are distended with oil. By pressing the cells (*g*) between two plates of glass, the contents will be squeezed out, and the structure will be seen as follows: — the vesicular transparent, amorphous cell-wall, finely granular matter, fat globules, and a granular nucleus (*h*), measuring about ·01 millim. and containing a hard transparent nucleolus. A few of the cells contain two nuclei. The blood-vessels, consisting of arteries and veins, form a rete around the bulbiform cæca, but do not appear to come in immediate contact with the secreting cells" (loc. cit.). The general plan of structure of the liver of the *Cephalopoda* is essentially the same; the hepatic ducts and follicles being clustered as in a raceme, and the follicles being crowded with biliary cells. In the *Loligo*, these follicles are described by Dr. Williams (op. cit.), as being themselves sacculated, by duplications of their membrane; and some of the biliary cells appear as if producing a new generation within themselves.

A very remarkable departure from the general type is presented by certain of the *Nudibranchiate* Mollusca, of which *Eolis* may be taken as the type. In these animals, the stomach gives off on either side a number of branches, which usually redivide, and then

Fig. 315.

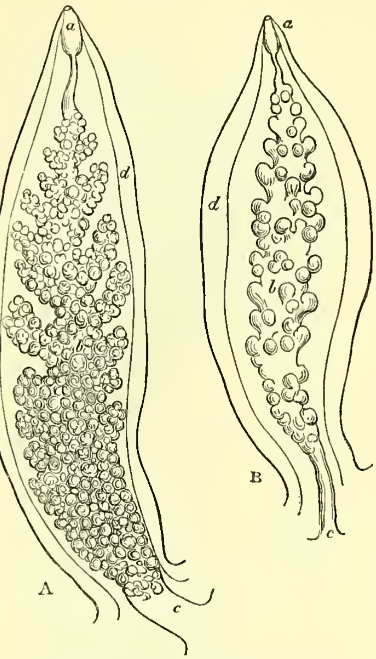


Eolis Farrani, showing the branchial papillæ. (*After Alder and Hancock.*)

give off smaller tubes, which are continued into the branchial papillæ that cover the dorsal surface (*fig.* 315.). "The prolongations of the branches that enter the papillæ undergo a considerable enlargement and change of form; and from the variety and brilliancy of their colouring are the chief attraction of these elegant little animals. The simplest form of this peculiar organ is met with in *Eolis concinna*, where it is a mere dilated tube, having its walls slightly waved, and the inner surface sprinkled with darkish granules. In *E. Farrani* (*fig.* 316. B) it still retains a considerable simplicity of structure, but becomes decidedly sacculated. The complexity is much increased in *E. olivacea*, in which it is produced into puckered follicles or sacculi; but in *E. papillosa* (*fig.* 316. A) it appears to attain its highest development. The central canal is there somewhat tortuous, and gives off on all sides variously sized, irregular, blind sacs, which are crowded with little compound follicles. The whole of the inner surface is lined with a thickish layer of irregular vesicles or globules, filled with numerous granules. These last, when submitted to a high magnifying power, are seen to be of various sizes, transparent, rounded, and nucleated. The whole of the internal surface of the gland is covered with vibratile cilia. These compound glands are evidently *biliary organs*, diffused throughout the several papillæ, and supplying the place of a compact liver, which is wanting in the body of these animals. The stomach

and biliary organs are so intimately connected in this genus, that it is not easy to point out

Fig. 316.



Biliary apparatus of Eolis.

A, branchial papilla of *E. papillosa*, exhibiting the gland *b* and the duct *c*; also an ovate vesicle, *a*, apparently an organ of defence, and at *d* the wall of the inner sheath; B, branchial papilla of *E. Farrani*, showing the same parts. (*After Alder and Hancock.*)

the limits of each; they appear to differ in different species. In *E. papillosa*, the central canal is evidently a continuation of the stomach, and the plicated internal membrane is not only continuous throughout it, but also passes into the lateral branches, which thus appear to form part of the same organ. On the other hand, we find in some species coloured granules, similar to those of the papillæ, partially lining the ramifications, as in *E. gracilis* and others; while in *E. despecta*, the central canal, all the ramifications, and the glands of the papillæ, are coloured and granulated alike, implying a greater diffusion of the biliary function. The food, after being partially digested in the stomachal pouch, is driven in detached portions through the alimentary system, by the alternate contractions of the pouch and great trunks leading from it; these contractions are only of a nature to produce an oscillatory motion, which serves to promote that intimate mixture of the alimentary matters with the hepatic and other secretions, necessary to the process of digestion." *

The intimate structure of the liver of *Vertebrated* animals is much more difficult of elucidation, and can scarcely be said to be yet satisfactorily determined. The organ presents more and more, as we ascend the series, a solid parenchymatous texture, which strikingly contrasts with its loosely lobulated racemose aspect, even in the highest Invertebrata. There is not the least difficulty in demonstrating that this parenchyma is composed of cells, which correspond in the nature of their contents, and, therefore, in their functional character, with those contained within the hepatic follicles of the Invertebrata; but the point of obscurity is the relation of these cells to the biliary ducts, the arrangement of whose ultimate ramifications has been rather a matter of surmise and inference, than of actual observation. It is very interesting to find, however, that in the lowest known Vertebrate the liver exists under the same rudimental and diffused type, as that which it exhibits in the lower Articulata. In the *Amphioxus*, or lancelet, the only vestige of a distinct hepatic organ is a large cæcum prolonged from the stomach, which is lined with greenish-yellow cells. But it is pointed out by Müller, that the intestinal canal itself has a layer of similar cells in its walls, so that the organ would seem to have the same diffused condition as that which it presents in the earth-worm. In all other fishes, however, the liver is a well-defined conglomerate gland, even the Myxinoids presenting a liver nearly as fully developed as that of the higher fishes, so that there is not here any such complete gradation as we usually meet elsewhere. Dr. T. Williams states that he has succeeded in tracing the ducts to their ultimate terminations in the liver of the Sole (*Solea vulgaris*), and the Flounder (*Platessa flexus*); and he describes them as ramifying like those of the Mollusca, and as ending in tubular cæca, without vesicular expansions. Within these cæca are found the hepatic cells, which usually, as in the Invertebrata, contain a large quantity of fat.* There is a remarkable diminution in the proportion of the adipose contents of the hepatic cells, and an increase in the granular constituents, in the class of Reptiles; and in Birds there is an almost total absence of adipose particles. The ultimate distribution of the bile-ducts, and their relation to the parenchyma, seem to be the same as in the Mammalia.

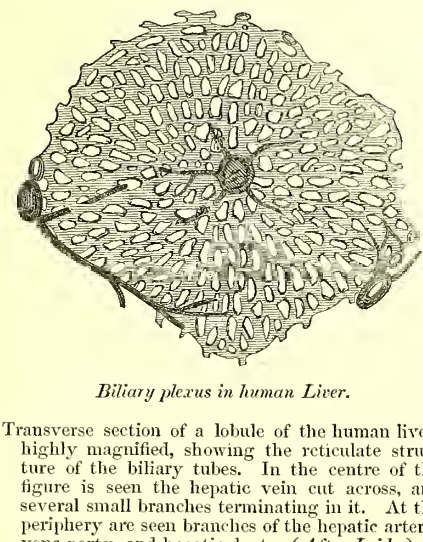
In the Mammalia, the liver is more or less distinctly divisible into minute lobules, each of them composed of a parenchyma of hepatic cells, through which the blood-vessels are distributed in a close and solid plexus. The hepatic cells appear to occupy the entire space left in the meshes of this plexus, the bile-ducts having been usually regarded as not traceable, under any form, into the interior of the lobule. Mr. Kiernan, however, has always regarded the bile-ducts as forming a plexus in the substance of the lobule, interlacing with the plexus of capillaries; his belief being chiefly founded on the anastomotic distribu-

* Alder and Hancock's Nudibranchiate Mollusca, Part I. I.

* Guy's Hospital Reports, 1846, p. 323.

tion of the bile-ducts in the left lateral ligament, which he considers as in itself a rudimental liver, exhibiting the structure of the entire organ in its most simple form. By Mr. Bowman it was supposed, that the limitary membrane forming the wall of the minute biliary ducts is not continued into the substance of the lobule, but that the epithelial lining of the ducts is continuous with the mass of hepatic cells which forms its parenchyma. There is an *a priori* improbability in such an idea, which would leave the glandular cells in immediate contact with the surface of the blood-vessels; an arrangement which does not exist in any other gland. We have been accustomed, therefore, to accord with the opinion of Dr. Thomas Williams*, that the limitary membrane of the bile-ducts is probably expanded over the whole of the parenchymatous portion of each lobule, moulding itself upon, and identifying itself with, the capsule or sheath of the vessels, and thus forming a sort of irregularly reticulated cavity, which may be described as the whole space occupied by the lobule, *minus* the series of passages containing the capillary plexus. The manner in which the lining membrane of the uterine sinuses with the cellular decidua are prolonged into the placenta, and reflected over the capillary tufts of the fœtal vessels, so as to divide the whole cavity of the placenta into a series of irregularly shaped chambers, freely communicating with each other, into which the maternal blood is conveyed, will convey an idea of this method of viewing the disposition of parts in the liver; the uterine sinuses representing the bile-ducts; the cellated cavities of the placenta, corresponding with the spaces occupied by the cells of the hepatie parenchyma; and the fœtal vessels occupying

Fig. 317.



Biliary plexus in human Liver.

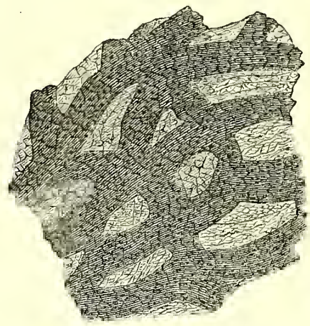
Transverse section of a lobule of the human liver, highly magnified, showing the reticulate structure of the biliary tubes. In the centre of the figure is seen the hepatic vein cut across, and several small branches terminating in it. At the periphery are seen branches of the hepatic artery, vena portæ, and hepatic duct. (*After Leidy.*)

* Op. cit. p. 330.

the place of the capillary plexus from which the secretion is formed.

The observations recently published by Dr. Leidy harmonise precisely with the view promulgated by Mr. Kiernan, and seem to confirm the idea that here, as elsewhere, the hepatic cells are enclosed in a limitary membrane. "The lobules are composed of an intertexture of biliary tubes (*fig*. 317.); and in the interspaces of the network the blood-vessels ramify and form among themselves an intricate anastomosis, the whole being intimately connected together by a combination of the white fibrous and the yellow elastic tissue. In

Fig. 318.

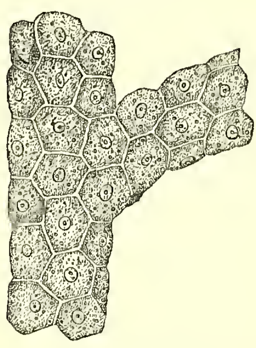


Biliary plexus in human Liver.

A small portion of the same section more highly magnified. The secreting cells are seen within the tubes; and in the interspaces of the latter, the fibrous tissue is represented. (*After Leidy.*)

structure, the biliary tubes (*figs*. 318, 319.) correspond with those of Invertebrata, consisting

Fig. 319.



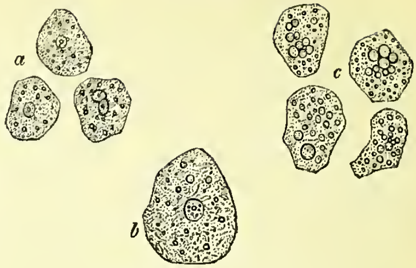
Biliary tubulus of human Liver.

Portion of a biliary tube from a fresh human liver, very highly magnified. The secreting cells are seen to be polygonal from mutual pressure. (*After Leidy.*)

of cylinders of basement membrane, containing numerous secreting cells, and the only difference exists in the arrangement, the free tubes of the lower animals becoming anastomosed on forming an intertexture in the Vertebrata. The tubuli vary in size in an unimportant degree in different animals, and also in the same animal, being generally from two

to two and a half times the diameter of the secreting cells. The tubes of one lobule are distinct from those of the neighbouring lobuli, or only communicate indirectly by means of the trunks or hepatic ducts, originating from the tubes, and lying in the interspaces of the lobuli. The secreting cells (*fig.* 320.) are irregularly angular or polygonal in form, from mutual pressure, and line the interior surface of the tubes. They vary in size in a moderate degree in different animals, and also in the same animal, appearing to depend upon certain conditions of the animal and liver."* We have ourselves verified these important observations to a certain point, not having been able to obtain a view of the regular and complete plexus of ducts figured and described by Dr. Leidy, but having satisfied ourselves that a system of canals, prolonged from the bile-ducts, exists in each lobule. The recently published observations of Dr. Natalis Guillot† are to the same effect. He has not been able, any more than ourselves, to distinguish membranous parietes around these canals; and he considers that they are simply channelled out in the parenchyma of the liver, the particles of which form its sole borders. It appears probable to us, however, that these canals correspond to the spaces left in the centre of the biliary tubuli of insects, &c.; and that the membranous walls, if they exist at all, would be found to invest the cells which immediately bound these passages.

Fig. 320.



Hepatic cells of human Liver.

a, three secreting cells of ordinary aspect; *b*, a secreting cell much more highly magnified, showing the central nucleus, granular particles, and oil globules; *c*, four secreting cells from a human liver in a state of fatty degeneration, showing a great increase of oil globules. (*After Leidy.*)

The *biliary cells* of the Mammalia (*fig.* 320.) usually contain a certain number of adipose particles; their size and number, however, vary considerably according to the food of the animal, the amount of exercise which it has been taking, and other circumstances. If an animal be very fat or well fed, especially with farinaceous or oleaginous substances, the proportion of adipose particles is much greater than in an animal moderately fed and taking much exercise. The size of the globules varies from that of mere points, scarcely distinguishable from the granular contents of the cells but by their intense blackness, up to one-fourth of the diameter of the cell. The finely granular matter is the portion from which the colour of the cell is derived; it seems to fill the space not occupied by the oil globules; and it often obscures the nucleus, so that the latter cannot be distinguished until acetic acid is added, which makes the granular matter more transparent without affecting the nucleus.

The following are the dimensions of the hepatic cells in various animals, according to the measurements of Dr. Leidy (loc. cit.).

	Long Diam.	Short Diam.	Nucleus.
	Millim.	Millim.	Millim.
Centipede (*Julus impressus*)	·0125		
Tumble bug (*Ateuchus volvens*)	·0225	·0125	
Katydid (*Platyphyllum concavum*)	·13	—	·0225
House-fly (*Musca domestica*)	·09	·06	·0225
Flesh-fly (*Musca carnaria*)	·09	—	·0275
Cray-fish (*Astacus affinis*)	·06 to ·02	—	·015
Snail (*Helix albolabris*)	·04 to ·02		
Slug (*Limax variegatus*)	·06 to ·03		
Rock-fish (*Labrax lineatus*)	·0275		
Minnow (*Hydrargira ornata*)	·02	·015	
Cat-fish (*Pimelodus catus*)	·0275		
Lizard (*Triton niger*)	·03	—	·0125
Frog (*Rana halecina*)	·03	·02	·005 to ·01
Terrapin (*Emys Terrapin*)	·03		
Snake (*Tropinodotus sirtalis*)	·02 to ·0275		
Boa (*Boa constrictor*)	·03	—	·015
Duck (*Anas acuta*)	·0175 to ·02	—	·006
Owl (*Strix brachyotos*)	·015	—	·005
Chicken (*Gallus domesticus*)	·016		
Ground Squirrel (*Sciurus striatus*)	·0175		
Gray Squirrel (*Sciurus Carolinensis*)	·015		
Rabbit (*Lepus Americanus*)	·03 to ·015	—	·01
Sloth (*Bradypus tridactylus*)	·0133		
Leopard (*Felis leopardus*)	·0125 to ·015		
Monkey (*Simia* ——— ?)	·015		
Man	·03 to ·015	·02	·009

* See American Journal of the Medical Sciences, Jan. 1848. Dr. Leidy does not specify the mode in which his preparations have been made; but we understand that his plan is to *dry* a small portion of injected liver, then to make as thin a slice of this as possible, and to examine this slice when restored to its original condition by moisture.

† Annales des Sciences Naturelles, Mars, 1848.

When the foregoing facts are duly weighed, the conclusion seems irresistible, that the cells containing the biliary matter are the only invariable constituents of the hepatic apparatus ; and that the manner in which these cells are arranged, and brought into relation with the blood-vessels, may vary indefinitely without producing any change in the character of the product. Consequently we cannot but look upon the biliary cells as the essential portion of the secreting structure ; and we must, in like manner, consider their agency as the essential part of the secretory function.

The same result has been obtained in all other cases in which the character of the secreted product is such, that it can be detected, when in a finely divided state, by the assistance of the microscope. Thus Prof. Goodsir has shown* that the pigmentary matter of the "ink" of the cuttle-fish is contained within the cells that line the ink-bag ; that the purple fluid secreted from the edge and internal surface of the mantle of *Ianthina fragilis* (which is supposed to have furnished the Tyrian dye) is contained within a layer of nucleated cells situated on the secreting surface ; and that a fluid resembling milk may be found in the cells contained within the ultimate follicles of the mammary gland in a lactating animal. We seem perfectly justified in concluding, therefore, that in cases where the transparency and freedom from colour of the secreted product prevent our distinguishing it in the cells of the organ by which it is eliminated (as in the case of the urine), it is nevertheless contained within them and eliminated by their agency.

It would probably be too much to affirm, that the elimination of the secretion always involves the continual *exuviation* of the cells, which are the instruments of the process. On the contrary, it seems probable that where the solid matter of the secretion bears but a small proportion to the liquid, and is in a state of perfect solution, the secreting cells may be continually drawing in their peculiar pabulum on the side nearest to the capillary network, and may be as constantly allowing it to transude by the free surface, so as to permit its passage into the cavity of the tube or follicle,—the cells themselves remaining attached to its walls, and continuing to perform this function for a considerable time. Such is probably the case with regard to the epithelial cells which line the tubuli of the kidney, and which eliminate the secretion of urine ; and those which line the tubes of the perspiratory glandule are probably as permanent.

In the case of cells, however, whose secretion contains a large quantity of solid matter, and especially where this is of an adipose character, it seems impossible to suppose that their contents can be given up, without the rupture or deliquescence of the cell-walls. This may take place either whilst the cells are yet in the follicles within which they were generated, or after they have been cast entire into the ducts, or have been even conveyed through them to their outlet. We have seen that in the biliary follicles of the Invertebrata, the discharged contents of secreting cells are usually to be met with, indicating that this rupture or deliquescence has taken place within the follicles ; and this is probably the fact in regard to the biliary cells in general. An extreme case of another kind is furnished by Mr. Harry Goodsir, in regard to the cells of an organ which is essentially one of secretion as to its structure, though its function has a different direction ; the peculiarity of this case being, that even after the complete exuviation of the cells, they retain so much of independent vitality, as to proceed in their own development to a stage much beyond that at which they were set free. The case referred to is that of the seminal secretion of the decapodous crustaceans ; the cells of which, when thrown out of the cæca of the testis, are very immature, and undergo important changes in their progress along the tubuli of that gland. The final changes, however, whereby they are fitted for the fertilisation of the ova, only take place after they have been discharged from the male organs, and have been lodged in the spermotheca of the female.*

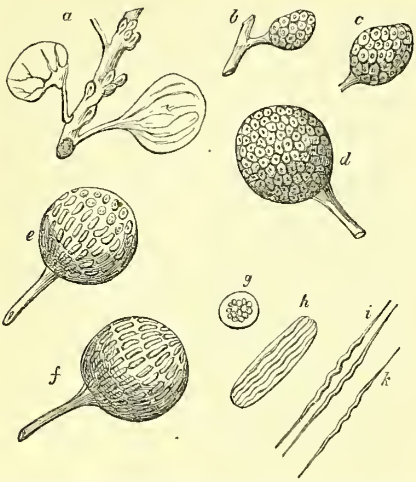
Now in every case in which the secreted product can only be given up by the rupture or solution of the cell-wall, it is obvious that there must be a continual succession or new production of the secreting cells ; and a question naturally arises as to their origin and mode of development. Few facts are as yet known upon this subject. It may, however, be stated with some certainty, that, in many of the simpler glands at least, the follicle with its contained secreting cells was originally a single closed cell, of which the secreting cells are the progeny. This is the case with the Peyerian glands, which are best known to us in this condition, but which afterwards open and discharge their contents into the intestinal canal. Dr. Allen Thomson has ascertained that the primitive condition of the gastric gland also is that of a closed vesicle ; and Henle has extended this view to the terminal follicles of the more complex secreting glands, which he considers to have originated in the same condition. The observations of Prof. Goodsir upon the testis of *Squalus cornubicus* show that this is the true account of the changes occurring in that organ ; the following stages being distinguishable in its structure, when it is in a condition of activity :—1st, Isolated nucleated cells attached to the side of the duct, and protruding as it were from its outer membrane (*fig.* 321. *a*). 2nd, A cell containing a few young cells grouped in a mass within it, the parent cell presenting itself more prominently on the side of the duct. 3d, A cell attached by a pedicle to the duct, the pedicle being tubular, and communicating with the duct ; the cell itself being pyriform, but closed and full of nucleated cells (*b*).

* Trans. of Royal Society of Edinburgh, 1842.

* Anatomical and Pathological Observations, p. 39.

4th, Cells larger than the last, assuming more of a globular form, still closed, full of nu-

Fig. 321.



Progressive development of vesicles of testis of Squalus cornubicus.

a, portion of duct with a few nucleated cells, the primary or germinal cells of the future acini, attached to its walls; *b*, *c*, *d*, *e*, *f*, primary cells, or acini, in successive stages; *g*, one of the secondary cells in an immature state; *h*, a secondary cell elongated into a cylinder, each cell of its composite nucleus elongated into a spiral; *i*, k, the spiral cells or spermatozoa free. (*After Goodsir.*)

cleated cells, and situated more towards the surface of the lobe (*c*). 5th, The full sized vesicles situated at the surface of the lobe, with their contents in various stages of development (*d*, *e*, *f*). These vesicles are spherical and perfectly closed; that part of the wall of each, which is attached to the hollow pedicle, forming a diaphragm across the passage, so that the vesicle has no communication with the ducts of the gland. The contained cells are at first spherical (*g*); but as the spermatozoa are gradually formed within them, they present a cylindrical form (*h*), and they are arranged within the vesicles in somewhat of a spiral manner (*f*). When the development has advanced to this stage, the diaphragms across the necks of the vesicles dissolve away or burst; and the bundles of spermatozoa float along the ducts of the gland, some of them separating into individual filaments (*i*, *k*). Besides the bodies now described, Prof. Goodsir has observed what he considers to be vesicles which have discharged their contents, and which are in a state of atrophy (*fig.* 322. *a*).

The testis of *Squalus cornubicus*, the functional history of which has been now given, is considered by Prof. Goodsir as a type of a number of glands, whose action takes place after the same manner; and he lays down the following general facts, which he has ascertained in regard to glands of this order.

"1st, The glandular parenchyma is in a constant state of change, passing through stages of development, maturity, and atrophy.

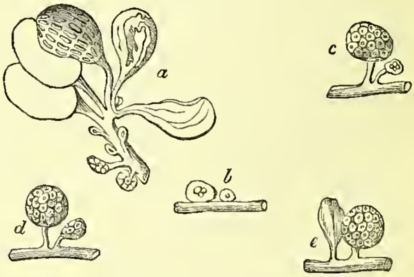
"2d. The state of change is contemporaneous with, and proportional to, the formation of the secretion, being rapid when the latter is profuse, and *vice versâ*.

"3d. The acinus is at first a single nucleated cell. From the nucleus of this cell others are produced. The parent-cell, however, does not dissolve away, but remains as a covering to the whole mass, and is appended to the extremity of the duct. Its cavity, therefore, as a consequence of its mode of development, has no communication with the duct. The original parent-cell begins to dissolve away, or to burst into the duct, at a period when its contents have attained their full maturity. This period varies in different glands, according to a law or laws peculiar to each of them.

"4. The secretion of a gland is not the product of the parent-cell of the acinus, but of its included mass of cells."*

An ideal representation of these successive changes is given in *fig.* 322. At *b* is seen a

Fig. 322.



Ideal representation of changes occurring in vesicular glands.

a, a bunch of acini in various states of development, maturity, and atrophy; *b*, *c*, *d*, are diagrams, arranged so as to illustrate the intimate nature of the changes which occur in vesicular glands when in a state of functional activity. (*After Goodsir.*)

portion of gland with two acini; one of them being a simple primary cell, the other being in a state of development, its nucleus producing young cells. At *c*, both acini are advancing; the second has almost reached maturity. At *d* the second acinus is ready to pour out its contents, and the first to take its place; and at *e*, the second acinus is thrown in a state of atrophy, whilst the first is become fully matured.

There is another set of glands, in which the follicles remain persistent for a much longer period, and continue to produce many successive generations of secreting cells; of these, the liver of the Crustacea may be taken as the type. From the appearances presented by these follicles, which have been already figured and detailed (*fig.* 312.), it seems fair to conclude, that the development of these cells

* Anatomical and Pathological Observations, p. 30.

takes place from the cæcal extremities; and Prof. Goodsir considers that they originate in a "germinal spot," which is the persistent nucleus of the parent cell, whose enlargement and connection with the gland forms the follicle. Growth in glands of this kind is regulated, according to him, by the following laws: —

"1st. Each follicle is virtually permanent, but actually in a constant state of development and growth.

"2d. This growth is contemporaneous with the function of the gland; that function being merely a part of the growth, and a consequence of the circumstances under which it occurs.

"3d. The vital action of some follicles is continuous, the germinal spot in each never ceasing to develope nucleated cells, which take on the action of, and become, primary secreting cells, as they advance along the follicle. The action of other follicles is periodical.

"4th. The wall, or germinal membrane, of the follicle is also (probably) in a state of progressive growth, acquiring additions to its length at the blind extremity, and becoming absorbed at its attached extremity. A progressive growth of this kind would account for the steady advance of its attached contents, and would also place the wall of the follicle in the same category with the primary vesicle, germinal membrane, or wall of the acinus, in the vesicular glands.

"5th. The primary secreting cells of the follicle are not always isolated. They are sometimes arranged in groups; and when they are so, each group is enclosed within its parent-cell, the group of cells advancing in development according to its position in the follicle, but never exceeding a particular size in each follicle." *

Prof. Goodsir further expresses the opinion, that there is an order of glands with very much elongated ducts, which do not possess "germinal spots" in particular situations, but in which these spots are diffused more uniformly over the whole internal surface of the tubes. To this order he refers the kidney in Man and the higher Vertebrata.

We have thought it right to give Prof. Goodsir's statements in full, as being in the main unquestionably correct; but we must express our own doubts as to that part of the doctrine which relates to the production of the secreting cells from distinct "germinal centres." We have examined a great number of membranes bearing an epithelial covering, without being able to discern these; and our own impression is, that the membrane itself is in a continual state of change, deriving from the blood-vessel, on the one side, the elements of the new growth, and yielding these up on the other.

Of the first *development* of secreting structures, a partial account was formerly given (see GLAND); and as this is on the whole in conformity with our present views, it is only requisite to add here the principal facts, ascertained by microscopic research since that article was written.

* Op. cit. p. 31.

The "plastic mass" of which the entire gland consists in its early condition, is now known to be composed of nucleated cells, which appear to be the parent-cells within which the true secreting cells are afterwards to be formed; these parent-cells themselves becoming the vesicles or follicles of the gland, by the establishment of communications between their cavities and the branches of the duct. It seems probable that some of the original component cells of the gland coalesce or break down altogether, so as to form the smaller ducts, the development of which has been observed to be quite independent of the protrusion of the principal duct, and of its primary branches, from the cavity of which it is a diverticulum. These last are properly intercellular passages; which, as Prof. Goodsir justly observes, "is an important consideration, inasmuch as it ranges them in the same category with the intercellular passages and secreting receptacles of vegetables."

Sources of the demand for the secreting function. — We must now consider in more detail, the causes which render the performance of this function essential to the active existence of every living being.

1. In the first place, nearly all the solids and fluids of the animal body are liable to continual decomposition and decay, in virtue of their peculiar chemical composition. That the living state antagonises this decay, and that decomposition can only take place after death, is a doctrine which long held undisputed sway in physiological science, but which is now generally admitted to be completely untenable. The resistance to decay which living organised structures present, is rather apparent than real; for it only continues so long as the circulating current continues to pass through or near them, carrying off the products of incipient decomposition, and replacing these by matter that is newly organised.

2. In the second place, a continual decomposition and decay of an organised fabric is involved in its mere *vegetative* existence. For every portion of it has an individual and independent life, and a limited duration of its own: each part, like the simple isolated cell of the lowest Cryptogamia, grows from a germ, arrives at maturity, and finally dies and decays; its *debris* being directly cast off, if the organ be external; but being taken again into the current of the circulation, to be eliminated by another channel, if the part have no direct communication with the surface of the body.* Perhaps the most obvious example of this general fact is presented to us in the vegetable

* The author believes that he may claim the credit of having been the first to enunciate this doctrine in definite terms, and as more than a mere hypothesis. (See Mr. Paget's Lectures on Nutrition, &c. Medical Gazette, 1847.)

economy. The cells of the woody stem have a long and almost indefinite duration, especially after they have become consolidated by the filling-up of their cavities with resinous or sclerogenous secretions; but those of the leaves, which are much more actively concerned in the vital operations, have a short and limited term of existence. The "fall of the leaf" is not the *cause* of the death and decay of the organ, but its *result*; for the decomposition of its tissues is already far advanced, when its detachment occurs: — its functions have been fulfilled; its term of life is expired; and it is cast off, to be replaced by a new development of cellular parenchyma, which in its turn will discharge the same important function, that of preparing the materials for the growth of the more permanent parts of the fabric. This kind of passive change is more constantly going on in the animal body than is usually supposed, especially during the period of its growth and increase. A good illustration is afforded by the deciduous or milk teeth. "We trace each of these developed from its germ, and, in the course of its own development, separating a portion of itself to be the germ of its successor; then each, having attained its due perfection, retains for a time its perfect state, and still lives though it does not grow. But at length, coincidently, not consequently, as the new tooth comes, the deciduous tooth dies; or rather, its crown dies, and is cast out like a dead hair; while its fang with the bony sheathing, and the vascular and nervous pulp, degenerates, and is absorbed. It is here especially to be observed, that the degeneration is accompanied by some spontaneous decomposition of the fang, for it could not be absorbed unless it was first so changed as to be soluble. And it is degeneration, not death, which precedes its removal; for when a tooth fang really dies, as that of the second tooth does in old age, then it is not absorbed, but is cast out entire, as a dead part. Such, or nearly such, it seems almost certain, is the process of assimilation everywhere; these may be taken as types of what occurs in other parts, for these are parts of complex organic structure and composition; and the teeth-pulps, which are absorbed as well as the fangs, are very vascular and sensitive, and therefore, we may be nearly sure, are subject to only the same laws as prevail in all equally organised parts."* All the epidermic and epithelial structures, including the secretory substance of glands, are continually undergoing the same change, by the exuviation of the old cells when their term of life is accomplished, and by the production of new ones; the durability being different according to the particular endowments of the part, but also varying with changes in the supply of blood, which increase or decrease its vital activity. Generally speaking, those parts which live most slowly are those of which the duration is the greatest, and in which there is consequently the least frequent change. Of the exuviation of epidermic structures *en masse* — a process altogether comparable to the fall of the leaf — we have striking examples in the entire desquamation of serpents, the moulting of the plumage in birds, and the shedding of the hair in the mammalia; and in the shedding of the antlers of the stag, we have an example of the exuviation of a highly organised and vascular part, which periodically dies, and which, being external, is cast off entire. "What means all this," says Mr. Paget*, "but that these organs have their severally appointed times, degenerate, die, are cast away, and in due time are replaced by others, which in their turn are to be developed to perfection, to live their life in the mature state, and in their turn to be cast off?" There can be little doubt that a similar change is continually taking place, with more or less activity, in every part of the internal structure; the products of decay, however, not being at once thrown off, because there is no direct means of getting rid of them; but being received back into the current of the circulation, to be eliminated by instruments expressly provided for that purpose.

Now, this interstitial change must take place constantly, during the whole life of the entire structure; but its activity varies according to certain conditions to which the fabric is subjected. One of the most important of these conditions is *heat*. It is well known that the tendency to decomposition, which is characteristic of organic compounds, is dependent upon the heat to which they are subjected: thus a compound which passes rapidly into decomposition at 100°, shall be much less prone to decay at 60°, and shall be permanent at 32°. And again, the vital activity of the several parts of the organised fabric is so dependent upon the same stimulus, that a very moderate depression of temperature serves to reduce it, or even to suspend it altogether. Now, when the activity of a part is thus reduced, so that it lives more slowly, its duration is proportionally increased, and interstitial change and renewal are scarcely required. We have obvious examples of this in the activity of all the functions in warm-blooded as compared with cold-blooded animals; in the superior energy of all the vital operations of birds, whose temperature is 10° or 12° above that of the Mammalia; and, on the other hand, in the torpor of cold-blooded animals, and of hybernating Mammalia, when the temperature of their bodies is depressed nearly to the freezing point. In the state of greatest activity, all parts of the body live fast; their duration is proportionally diminished; interstitial death and decomposition are continually taking place; the results of this decomposition have to be got rid of from the body; and a corresponding demand is set up for nutrient materials, to be applied to the renovation of the structure. On the other hand, a reduction of temperature, which di-

* Paget, Lectures on Nutrition, &c.

* Loc. cit.

minishes the vital activity of the living tissues, tends also to increase their duration; and this not merely by causing them to live more slowly, but by obstructing the spontaneous decomposition of their organic constituents. This reduction may be carried to such an extent as, on the one hand, to suspend all vital action, whilst, on the other, it prevents decomposition; so that the body remains in a state of *dormant vitality*, undergoing no change whatever for an indefinite period, but ready for a renewal of its vital activity whenever an increase of temperature shall awaken its slumbering energies. (See LIFE.) The more nearly a living structure is reduced to this condition, the less interstitial change does it undergo; the less nutriment, therefore, does it require; and the less effete matter is there to be thrown off.

The activity of that spontaneous interstitial change, which takes place as a part of the mere vegetative life of the animal organism, further varies in accordance with the period of life of the fabric taken as a whole. Thus all the tissues, even those most consolidated, are undergoing continual changes in the young animal, in which the processes of decay and renewal go on much faster than in the adult; and in the adult, than in the aged person. Thus we have seen that the duration of the deciduous teeth is very limited; whilst that of the permanent teeth may be coeval with the life of the entire animal, little or no interstitial change taking place in them during the whole of that period. So also the component parts of the bony structure, which in the adult are almost permanent, and in the aged become so remarkably solidified that little or no interstitial change *can* take place in them, are liable in the growing child to continual decomposition; no part of the substance of a long bone having any permanence, but the interior layers of the shaft being removed (by *absorption*, it is commonly said, but the absorption being probably in reality preceded by *degeneration*), so as to enlarge the medullary cavity, in proportion as new layers are formed on the external surface. This may be partly accounted for by the imperfect degree in which, so long as the entire organism is undergoing rapid increase, the normal structure is developed in any one portion of it; for as the degree of consolidation is less, the tendency to decay will be greater. But this explanation is not in itself sufficient, and we must be content, for the present, to regard it as a general law, that, with the advance of life, the duration of the individual components of the organism increases, whilst their functional activity diminishes. (See AGE.)

3. But, in the third place, the exercise of the *Animal* functions seems to be essentially destructive of the structures which are their instruments; every operation of the muscular and nervous systems appearing to require, as its necessary condition, a disintegration of a certain portion of their tissues, probably by the union of their elements with the oxygen supplied by arterial blood. The duration of the existence of these tissues may be clearly shown to vary inversely with the use that is made of them, being less as their functional activity is greater. Hence, when an animal is very inactive, it requires but very little nutrition; if in moderate activity, there is a moderate demand for food; but if its nervous and muscular energy be frequently and powerfully called into exercise, the supply of aliment must be increased, in order to maintain the vigour of the system. In like manner, the amount of the effete matters, which result from the disintegration and decay of those tissues, must increase with their activity, and diminish in proportion to their freedom from exertion.

4. A necessity for the secreting process may further arise within the system from the ingestion of superfluous aliment. This would not be the case, if the amount of food prepared by the digestive process, and taken up by absorption into the current of the circulation, were always strictly proportional to the demand for nutriment created by the wants of the system. There can be no doubt that almost every individual who is not restrained by considerations of economy, or by fear of unpleasant consequences, from indulging his natural appetite, really takes in more food than the wants of his system absolutely require; and all that is not appropriated to the reparation of the waste, or to the increase in the weight of the body, must be thrown off by the excreting organs, without having ever been converted into organised tissue. The superfluous portion of the non-azotised constituents of the food may be deposited as fat in those individuals who have a disposition to the production of adipose tissue; but the azotised constituents cannot be applied in like manner to the unlimited increase of the muscular and other tissues; and that which is not speedily converted into organisable material, and drawn off from the blood by conversion into organised tissue, would accumulate injuriously in the circulating current, and would taint it by decomposition, if it were not continually removed by the excreting processes.

5. Again, it cannot be deemed improbable that the changes which the crude aliment undergoes, from the time of its first reception into the absorbents and blood-vessels, to that of its conversion into organised tissues and into the materials of secretions eliminated for some special purpose in the economy, involve the liberation of many products, of which the elements are superfluous, and therefore injurious to the system if retained within it. The condition of organic chemistry, however, is not at present such as to admit of anything being advanced with certainty under this head.

From these various sources, then, a large amount of effete matter is being continually received back from the tissues into the current of the circulation, or is generated in the blood by the changes to which it is itself subject; and it is one great object of the secreting apparatus, to free that fluid of the products which would rapidly accumulate in it, but for the

provision which is thus made for their removal.

The first product of the decay of all organised structures is *carbonic acid;* and this is the one which is most constantly and rapidly accumulating in the system, and the retention of which, therefore, within the body, is the most injurious. Accordingly, we find two organs, the lungs and the skin, specially destined to remove it; and their action is so contrived, that whilst eliminating a noxious product, they shall be subservient to the introduction into the system of the vivifying element, oxygen, without a continued supply of which the animal functions cannot be long kept in activity, nor the heat of the body sustained.

The skin, again, is one of the organs for the removal of the superfluous *water* from the body; and the exhalation from its surface, the amount of which varies with the degree of external heat, serves the additional purpose of keeping down the temperature to its normal standard. The lungs also regularly throw off a considerable quantity of water, of which the amount is but little subject to variation, and of which some portion may have been actually generated in the blood by the union of hydrogen and oxygen. And the kidneys, the structure of which is beautifully adapted to eliminate the superfluous fluid by simple mechanical transudation, draw off the residue; the amount of water which they remove being the complement of that exhaled by the skin.

All azotised substances have a tendency, during their decomposition, to throw off *nitrogen;* and in the animal body this element is for the most part eliminated by the kidneys, entering largely into the composition of the urinary secretion. Thus we find *urea* to contain a larger proportion of nitrogen than exists in any other organic compound; and uric acid, hippuric acid, kreatine and kreatinine, and other compounds, which are characteristic elements of this secretion in different animals, are all rich in nitrogen. But it is not only by the kidneys that azotised substances are thrown off, for the solid matter exuded from the skin closely corresponds in composition with that of the urinary secretion; and urea has been detected in it.

The biliary secretion is peculiarly rich in *hydrocarbon,* and may probably be regarded as the complement of that of the kidneys; it having been shown by Liebig, that if the empirical formulæ for the bile and urine be added together, the result comes very near to the empirical formula for blood. Of this secretion, a part is certainly destined to be immediately carried off through the intestinal canal; but another part seems to be re-absorbed, in combination with the fatty matters of the food, and to be subsequently thrown off by the respiratory process. What proportion is applied to each purpose cannot be definitely stated, and probably varies much with circumstances.

But besides the metamorphosis of the organised tissues, and of the organic elements of the blood, into the definite (generally crystalline) compounds, which are the characteristic elements of the secretions already mentioned, it would seem that a portion of the effete matters take on a *putrescent* state; and that for the elimination of these a special and most appropriate apparatus is provided, namely, the extensive system of glandulæ in the wall of the intestinal canal. As this point has been much less attended to than its importance deserves, it seems desirable to dwell upon it here in some detail. It has been too much the custom to regard the fæcal evacuations as little else than the indigestible residue of the food, mingled with portions of the biliary and pancreatic secretions; whereas we think that a little consideration will show, that the peculiarly *fæcal* matter is a real excretion, which must have been eliminated from the blood by the intestinal glandulæ. The undigested residue of the food may form a greater or a smaller proportion of the *bulk* of the evacuation, according to the nature of the ingesta and the completeness of the digestive process. When the alimentary canal is in an irritable state, and the aliment is hurried through it without time being allowed for the proper action of the gastric secretions, a considerable part of it may be recovered from the fæces in an almost unchanged condition. It has been found that even starch vesicles, if not ruptured by the masticating process, or by the heat employed in the preparation of the food, resist the digestive process so completely as not to give up their contents; being readily detectible in the fæces, in an entire state, by the assistance of the microscope. Further, there is no evidence whatever, that the undigested residue of the food *could* acquire the fæcal character, during the short period which suffices in the state of health for its transmission along the alimentary canal; and there is every reason to believe the contrary, since the substances which resist the action of the gastric solvent are precisely those which have the least tendency to this kind of decomposition. Moreover, in purely Carnivorous animals, and in Man when he adopts the same diet, fæcal matter is still voided, though in smaller quantity than in Herbivora. The case is still stronger in regard to sucking animals; since the milk by which they are supported is pure nutriment, of which no part can be supposed to pass directly into the fæces. The continued evacuation of fæcal matter when little or no food has been taken in, the large quantity brought off by purgative medicines after the bowels have been completely emptied of their solid contents, and the colliquative diarrhœa which so frequently occurs at the close of exhausting diseases and previously to death by starvation, are so many obvious confirmations of the same view. And Dr. Williams* has pointed out many pathological phenomena, which indicate that the inflammation and ul-

* Principles of Medicine, 2d ed. p. 248. *note.*

ceration of the intestinal glandulæ, which is so frequent a complication of fevers and of other diseases induced by the presence of a morbid poison in the blood, results from the continued operation, upon their own structure, of the noxious matter which these glandulæ are endeavouring to eliminate from the system. This view has derived important confirmation from experiments recently made by Prof. Liebig; these having indicated that the substances to which the fæces owe their peculiar fœtor may be artificially produced by the imperfect oxidation of albuminous compounds.* The immense relief frequently given by an attack of diarrhœa, which spontaneously eliminates morbific matters that were operating prejudicially on the system, and the corresponding effects of mild purgatives, which excite the secreting action of these glandulæ, furnish additional evidence, if such be required, to the same effect. It is obviously important in a therapeutic point of view, that definite ideas should be entertained on this subject; and although it may be difficult to obtain positive proof of the position here advanced, — that it is the special function of the glandulæ of the lower part of the small intestines, and at the upper part of the large, to eliminate from the blood the putrescent matter which results from the disintegration of the tissues,—it will scarely be denied that a strong probability has been established by the foregoing evidence, in favour of such a view.

The interruption of any of these excreting processes, by causing an accumulation of effete matters in the blood, occasions speedy death (see EXCRETION); and Dr. Marshall Hall was perfectly correct in affirming†, that the functions of *egestion* are more immediately necessary to the maintenance of life than those of *ingestion*. For whilst most animals may live for a considerable time without food, and many without oxygen, there are none which are not speedily killed (unless previously reduced to a state of torpidity) by the complete suspension of the excretory operations.

In all the cases hitherto considered, the necessity for the secreting function arises out of the changes which are continually taking place in the system at large, and which tend to produce an injurious effect upon the character of the blood. We have seen, however, that even the act of liberation of effete or superfluous matters is frequently made to answer some ulterior purpose in the economy; and we are thus led to notice the other class of secretions, in which this ulterior purpose appears to be the principal, if not the sole, object of their separation. The variety of these, however, is so great, and their uses are so different, that no general statement can be made regarding them. It must suffice to refer to a few examples, such as will show their importance in the economy of the different animals which form them. The secretion of tears for the cleansing and lubrication of the surface of the eye; the salivary, gastric, and pancreatic secretions for the reduction and solution of the food; the mammary secretion for the nutrition of the offspring; the sebaceous secretions for the lubrication of the skin; the mucous secretions for the protection of the mucous membranes; the poisonous secretions of certain serpents, insects, &c.; the glutinous secretion with which the silkworm weaves its cocoon and the spider its web; the pigmentary secretion of the cuttle-fish; the colouring matter secreted by the mantle of many of the mollusca for imparting various hues to their shells; the strongly odorous secretions of many animals, which seem generally attractive to those of their own kind, but repulsive to others; together with many others that might be cited, are sufficient to indicate that the formation of even a very small amount of some peculiar product may be essential to the well-being of the animal which furnishes it; by contributing to the due performance of one or more of its vital functions, or by the protection it affords to some important organ.

Existence of the elements of secretions in the blood. — The chemical proofs which have been recently obtained of the presence of the characteristic elements of certain secreted fluids in healthy blood, have afforded the most complete evidence of that which was previously highly probable, namely, that the office of the secreting organs is more that of selection and separation than that of conversion. The proof is most complete and satisfactory in regard to the chief elements of the urinary secretion; but inferential evidence scarcely less conclusive exists with regard to several other substances.

The presence of *urea* in the blood was first clearly shown by Prevost and Dumas*, who found that when the functions of the kidneys were destroyed, either by the extirpation of those organs, or by ligature of the renal arteries, urea could be detected in the circulating fluids after a short period. Similar results have been obtained by other experimenters; and pathological observation, in cases where the normal secretion has been suspended or greatly diminished (as in the advanced stages of Bright's disease), has equally shown that under such circumstances the presence of urea manifests itself in the blood when duly analysed.† An interesting case has lately been put on record by Dr. Shearman, in which the secretion of true urine being temporarily suspended, in consequence of accident (a watery fluid, containing neither urea, uric acid, nor the urates, being all that was passed for some days), urea was obtained in considerable quantity from the serum of blood drawn from the arm.‡ It would be difficult to explain such facts in any other way, than by supposing that urea is constantly being generated in the system, and

* Animal Chemistry, 3d ed. p. 154.

† Gulstonian Lectures, 1842.

* Annales de Chimie, tom. xxiii.

† See Christison in Edinb. Med. and Surg. Journ. 1829.

‡ Edinb. Monthly Journal, March, 1848.

being received into the circulating current; that being eliminated by the kidneys, in the state of health, as fast as it is formed, it has no time to accumulate in the blood; but that when such elimination is checked or diminished, whilst its formation continues, the minute quantity originally present gradually increases, so as at last to become easily detectible by chemical processes. However probable such an explanation might be felt to be, it is yet satisfactory to find it confirmed by direct experiment.* Simon and Marchand some time since obtained satisfactory evidence of the presence of urea in the healthy blood of the cow; and Dr. Garrod has lately succeeded in obtaining urea from the serum of healthy human blood. The amount, as might be anticipated, was very small, only 1-200th of a grain of urea being procurable from 1000 grains of serum.†

The pre-existence of *uric acid* in the blood might in like manner be inferred from the well-known fact of its deposition in gouty concretions: this inference, also, has been confirmed by Dr. Garrod, who has discovered uric acid in the blood of gouty subjects. It might be not unreasonably asserted, however, that the presence of uric acid in the blood is the result of a disordered condition of the system generally; and it is hence satisfactory to find that in this case also Dr. Garrod has succeeded in obtaining the substance itself from healthy blood. He states that the amount seems liable to considerable variation, and to have some relation to the period that has elapsed since food was last taken, being least where this was longest: thus in one instance, where food had not been taken for twenty-four hours, 1000 grains of serum yielded only 2-1000ths of a grain of uric acid; whilst a similar quantity of serum from the blood of other healthy subjects yielded 7-1000ths; and a like amount of serum from the blood of a man of full habit, but otherwise healthy, yielded 37-1000ths of a grain of uric acid.

Of *hippuric acid*, which exists in small quantity in human urine, but in much larger amount in the urine of herbivorous animals, Dr. Garrod states (loc. cit.) that he thinks he has detected traces in the blood.

There can be no reasonable doubt that *kreatine* and *kreatinine* are normal elements of healthy blood, since they are constituents of the "juice of flesh," which seems to be the result of the disintegration of the muscular tissue, and must be taken into the circulating current to be conveyed from the muscles into the urine, where we again meet with these substances.

In like manner it is probable that *lactic* acid is normally present in the blood in very minute proportion; for it abounds in the juice of flesh, and must be taken into the current of the circulation, in order to be eliminated from the body. In the healthy state it seems to be eliminated through the respiratory organs as fast as it is generated; being converted by oxidation into carbonic acid and water. It was formerly supposed to be a normal constituent of the urine; but it has been clearly proved by Liebig not to have a real existence there. Even when lactate of potash has been introduced by the stomach, the potash is thrown out by the kidneys in combination with other acids, the lactic acid not being eliminated in the urine, but passed off through the lungs. In certain diseased states of the system, however, lactic acid unquestionably presents itself in the gastric, urinary, and cutaneous secretions; and as it has been shown to be one of the results of the disintegration of the muscular tissue, its pre-existence in the blood cannot be reasonably doubted.

The less definite nature of the constituents of *bile* prevents them from being as certainly recognised in the blood as those of urine have been; nevertheless, the evidence of their pre-existence in the circulating fluids is sufficiently clear. Thus *cholesterine* may be obtained from the serum of the blood by an analytical process of no great complexity; and its presence there is also manifested by its occasional deposit, as a result of diseased action, in other parts of the body, especially in the fluids of local dropsies, as hydrocele, ovarian dropsy, &c. Again, the *colouring matter* of the bile seems to be nearly identical with certain normal elements of the blood, since the hue exhibited by a departing ecchymosis is identical with the characteristic colour of bile. In cases of jaundice, the presence of the colouring matter in the blood is often made evident, not merely by the communication of its peculiar hue to the several tissues and secretions of the body, but also by the tint visible in the serum of the blood itself. It would seem probable, however, that in many of these cases there has been an actual re-absorption of the biliary matter subsequently to its elimination by the liver, as a consequence of obstruction to its exit by the gall duct. But in the most severe and rapidly fatal cases of jaundice, as pointed out by Dr. Alison*, the secreting process has never taken place, and the colouring matter must then have been generated in the blood itself. Neither cholesterine, nor the colouring matter of bile, seem to exert the poisonous influence on the nervous system which is manifested in the cases alluded to; and it is probable that this must proceed from the accumulation of the peculiar organic constituent of the bile. As the precise nature of this, however, is still a matter of discussion amongst chemists, we cannot be surprised that it has not yet been obtained by analysis from the blood.

* Dr. Prout states (On Stomach and Renal Diseases, 5th ed. p. 531. *note*), that when engaged in examining the blood in the year 1816, he found urea (or a substance having most of its properties) in that fluid; but not crediting the fact, and thinking it might be accidental, he did not pursue the enquiry, though he made a memorandum of the circumstance.

† Lancet, July 8. 1848.

* Edinb. Med and Surg. Journ. vol. xliv.

The proof that the constituents of the *milk* pre-exist in the blood, is rather inferential than direct. That the *caseine* (although so like the albumen of the blood that we might imagine it to be a mere modification of it, effected in the act of secretion) is, in reality, specially prepared in the circulating current, would appear from the fact that, during pregnancy, a substance, *kiestein*, having a close relation to it, is eliminated by the urine, and that this substance disappears from the urine within a few days after parturition, the mammary secretion being then fairly established. Perhaps, however, the most remarkable evidence to the same effect is afforded by cases of *metastasis* of the mammary secretion, of which an account will be presently given; and on the same kind of evidence rests the proof of the pre-existence of the other characteristic elements of the mammary secretion in the blood.

With regard, however, to the elements of other secretions, the evidence is less clear as to the state in which they exist previously to their elimination by the secreting apparatus. The fact would appear to be, however, that the solid constituents of most of them are little else than constituents of the blood itself, either pure or but slightly altered. Thus in the lachrymal fluid, the saliva, the gastric and pancreatic juices, and the serous fluid of areolar tissue and of serous and synovial membranes, we find little else than saline matters, which are normal constituents of the serum of the blood, with one or more organic compounds, that seem like albumen in a state of change. The repression of *these* secretions does not produce any deleterious effect upon the general system, otherwise than as impairing or preventing the performance of the function to which they are subservient; whence it may be inferred, that the selection of the secreted products from the blood is made in these cases, not for the sake of purifying the circulating fluid from any matter that would be noxious if retained, but merely for some minor purposes in the economy, to which these simple fluids are adequate.

Metastasis of secretion. — Although the number and variety of the secretions become greater in proportion to the increased complexity of the nutritive processes in the higher classes, and although each appears as if it could be formed by its own organ alone, yet we may observe, even in the highest animals, some traces of the community of function which characterises the general surface of the lowest. It has been shown that, although the products of secretion are so different, the elementary structure of all glands is the same; that wherever there is a free secreting surface it may be regarded as an extension of the general envelope of the body, or of the reflexion of it which lines the digestive cavity; that its epithelium is continuous with the epidermis of the integument, or with the epithelium of the mucous membrane from which it is prolonged; and that the peculiar principles of the secreted products pre-exist in the blood, in a form at least closely allied to that which they assume after their separation. Now, it may be stated as a general law in physiology, that in cases *where the different functions are highly specialised* (that is, where every one has its special and distinct organ for its own purpose alone), *the general structure retains, more or less, the primitive community of function which characterised it in the lowest grade of development.** Thus, although the functions of absorption and respiration have special organs provided for them in the higher animals, they are not altogether restricted to these, but may be performed in part by the general surface, which (although the special organ for exhalation) permits the passage of fluid into the interior of the system, and allows the interchange of gases between the blood and the air. In the same manner, we find that the functions of secretion being equally performed in the lowest animals by the whole surface, whilst in the highest there is a complicated apparatus of glandular organs, to each of which some special division of the function is assigned, either the general muco-cutaneous surface, or some one of its subdivisions or prolongations, is able to take on in some degree the function of another gland whose functions may be suspended. This truth was well known to Haller, who asserted that almost all secretions may, under the influence of disease, be formed by each and every secreting organ.† This statement, however, needs to be received with some limitation, and it would be probably safest to restrict it to the *excretions*, whose elements pre-exist in the blood, and accumulate there when the elimination of them by their natural channel is suspended. We shall now consider some of the more remarkable examples of the metastasis of secretion.

It seems to be established by a great mass of observations, that *urine*, or a fluid presenting its essential characters, may pass off by the mucous membrane of the intestinal canal, by the salivary, lachrymal, and mammary glands, by the testes, by the ears, nose, and navel, by parts of the ordinary cutaneous surface, and even by serous membranes, such as the arachnoid lining the ventricles of the brain, the pleura, and the peritoneum. A considerable number of such cases was collected by Haller ‡ : many more were brought together by Nysten § ; more recently Burdach has furnished a full summary of the most important phenomena of the kind ‖ ; and Dr. Laycock has compiled a valuable summary of cases of urinary metastasis occurring as complications of hysteria.¶ The following table

* See the author's "Principles of General and Comparative Physiology," 2d ed § 243.

† Elementa Physiologiæ, tom. ii. p. 369.

‡ Ibid. p. 370.

§ Recherches de Physiologie et de Chimie pathologique, p. 265.

‖ Traité de Physiologie (Jourdan's Translation) vol. viii. p. 248, *et seq.*

¶ Edinb. Med. and Surg. Journ. 1838.

of cases referred to by the last of these authors will give some idea of the relative frequency of the different forms of this curious affection: —

Vomit.	Stool.	Ears.	Eyes.	Saliva.	Nose.	Mammæ.	Navel.	Skin.	Total.
33	20	4	4	5	3	4	34	17	124

It is to be borne in mind, however, that cases of hysterical ischuria are frequently complicated with that strange moral perversion, which leads to the most persevering and ingenious attempts at deceit; and there can be little doubt that a good many of the instances on record, especially of urinous vomiting, are by no means veritable examples of metastasis. The proofs of the fact we are seeking to establish are, therefore, much more satisfactory when drawn from experiments upon animals, or from pathological observations, about which, from their very nature, there can be no mistake.

Thus Mayer * found that when the two kidneys were extirpated in the guinea-pig, the cavities of the peritoneum and the pleura, the ventricles of the brain, the stomach, and the intestinal canal, contained a brownish liquid having the odour of urine; that the tears exhaled the same odour; that the gall-bladder contained a brownish liquid not resembling bile; and that the testicles, the epididymis, the vasa deferentia, and the vesiculæ seminales, were gorged with a liquid perfectly similar to urine. Chirac and Helvetius are quoted by Haller as having tied the renal arteries in dogs, and having then remarked that a urinous fluid was passed off from the stomach by vomiting. A remarkable case is quoted by Nysten from Zeviani, in which a young woman having received an incised wound on the external genitals, which would not heal, the urine gradually became more scanty, and at last none could be passed even with the assistance of the catheter; at last dropsy supervened, with sweats of a urinous odour, and vomiting of a urinous fluid, which continued daily for thirty-three years. On post-mortem examination, the kidneys were found disorganised, the right ureter entirely obliterated and the left nearly so, and the bladder contracted to the size of a pigeon's egg. In some other instances, the urine appears to have been secreted, and then re-absorbed in consequence of some obstruction to its exit through the urinary passages. Thus Nysten quotes from Wrisberg a case in which, the urethra having been partially obstructed for ten years by an enlarged prostate, the bladder was so distended as to contain ten pounds of urine; and the serosity of the pericardium and of the vesicles of the brain exhaled a urinous odour. He cites other instances in which the presence of calculi in the bladder prevented the due discharge of the secretion; and in which a urinous liquid was ejected from the stomach by vomiting, or was discharged by stool. A still more remarkable case is recorded, of a girl born without either anus or external genitals, who nevertheless remained in good health to the age of fifteen years, passing her urine from the nipples, and getting rid of fæcal matters by vomiting. There are cases, moreover, in which it would seem that the mucous lining of the urinary bladder must have had a special power of secreting urine; the usual discharge having taken place to the end of life, when, as appeared by post-mortem examination, the kidneys were so completely disorganised that they could not have furnished it; or, having been prevented by original malformation, or by ligature of the urethra, from discharging it into the bladder. A considerable number of these have been collected by Burdach.* In all the older statements of this kind, there is a deficiency of evidence that the fluids were really urinous, urea not having been obtained from them by chemical analysis, and the smell having been chiefly relied upon. The urinous odour, however, when distinct, is probably nearly as good an indication of the presence of the most characteristic constituent of human urine, as is the sight of the urea in its separated form. The passage of a urinous fluid from the skin has been frequently observed in cases in which the renal secretion was scanty; and the critical sweats, by which attacks of gout sometimes terminate, contain urates and phosphates in such abundance as to form a powdery deposit on the surface. It has lately been ascertained, that in warm climates urea is an element of the perspiration even of healthy persons.†

The metastasis of the *biliary* secretion is familiar to every practitioner, as being the change on which *jaundice* is dependent. It is not, however, in every case of yellowish brown discolouration of the tissues, that we are to impute such discolouration to the presence of biliary matter; and we can only safely do so, when we have at the same time evidence of concurrent disturbance of the biliary apparatus. This disturbance may be of two kinds: either the secreting function of the liver itself may be diminished or suspended, so that the original elements of bile accumulate in the blood; or, the secretion being formed by it as usual, its discharge may be prevented by obstruction of the gall-ducts, so that it is re-absorbed into the blood. The former condition is much the most dangerous of the two; the re-absorption of the secretion after it has been once eliminated not being

* Zeitschrift für Physiologie, tom. ii. p. 270.

* Op. cit. pp. 253, 254.

† Landerer in Heller's Archiv. vol. iv. p. 196.

nearly as injurious as the cessation of the eliminating process. In either case, the urinary apparatus is the principal channel through which the biliary matter is eliminated; the urine becomes tinged with the colouring principle of bile, being sometimes of a yellowish or orange hue, and sometimes of a brown colour with a considerable sediment; and the presence of the most characteristic constituents of the bile has been determined in the urine. The same result presents itself when the biliary duct has been artificially obstructed by ligature. Other secretions have been found tinged with the colouring matter of bile: thus the pancreatic fluid has been seen of a yellow colour in jaundice; and the milk has presented not merely the hue, but the characteristic bitterness, of the biliary secretion. The cutaneous transpiration is not unfrequently so much impregnated with biliary matter, as to communicate the tinge to the linen covering the skin; and even the sputa of patients affected with bilious fevers have been observed to be similarly coloured, and have been found to contain biliary matter. The secretions of serous membranes, also, have been frequently seen to present the characteristic hue of bile; and biliary matter has been detected, by analysis, in the fluid of the pleural and peritoneal cavities.

Biliary matter, however, when unduly present in the circulating current, is not removed from it by the secreting organs alone; for it seems to be withdrawn also in the ordinary operations of nutrition, entering into combination with the solid tissues. Thus, in persons affected with jaundice, we find the skin, the mucous and serous membranes, the lymphatic glands, the brain, the fibrous tissues, the cartilages, the bones and teeth, and even the hair, penetrated with the colouring matter of the bile, which they must have withdrawn from the blood, and which seems to have a particular affinity for the gelatinous tissues.

Many instances are on record, in which the secretion of *milk* has apparently been transferred from the mammary glands to some other surface. It might be expected, from what has been already stated regarding kiestine, that the kidneys should eliminate the constituents of the secretion when the mammary glands are unable to do so. Several cases in which this happened are referred to by Voigtel.* One of these, strange to say, was a *male*, who was suffering under tumefaction of the mammary glands, accompanying an attack of catarrh. It is well known that the secretion of milk may be formed by the mammary gland of the male under particular circumstances; but it could scarcely have been anticipated that it would be produced and eliminated through any other channel. A case has been recorded by Koller, however, in which this was unequivocally the case. A young man, suffering under various ailments, was affected with a vesicular eruption on the skin of the scrotum, which was considerably distended, and on the thighs; and these vesicles discharged a large quantity of a whitish fluid, of somewhat spermatic odour, in which Löwig detected butter, caseous matter, sugar of milk, and alkaline and earthy salts. A fluid, having the appearance of milk, has also been transuded from the skin of the umbilicus, of the axillæ, of the groins, and of the back; from the gastro-intestinal mucous membrane; from the mucous membrane of the genitals; and from the surface of an ulcer. The following seems an unequivocal case of the vicarious secretion of milk by a very unusual channel.

"A lady of delicate constitution (with a predisposition to pneumonia) was prevented from suckling her first child, as she desired, by the following circumstance. Soon after her delivery she had a severe fever, during which her breasts became very large and hard; the nipples were swollen and firm; and there was evidently an abundant secretion of milk; but neither the sucking of the infant, nor any artificial means, could draw a single drop of fluid from the swollen glands. It was clear that the milk-tubes were closed; and as the breasts continued to grow larger and more painful, purgatives and other means were employed to check the secretion of milk. After three days the fever somewhat diminished, and was replaced by a constant cough, which was at first dry, but soon after was followed by the expectoration of simple mucus. After this the cough diminished in severity, and the expectoration became easy; but the sputa were no longer mucous, but were composed of a liquid which had all the physical characters of genuine milk. This continued for fifteen days, the quantity of milk expectorated amounting to three ounces or more in the twenty-four hours. The breasts gradually diminished in size; and by the time that the expectoration ceased, they had regained their natural dimensions. The same complete obstacle to the flow of milk from the nipples recurred after the births of four children successively, with the same sequel. After the sixth, she had the same symptoms of fever, but this time they were not followed by bronchitis, or the expectoration of milk; she had in their stead copious sweatings, which, with other severe symptoms, reduced her to a cachectic state, and terminated fatally in a fortnight."*

Although the *menstrual flux* cannot be regarded in the light of an ordinary secretion, since it consists in great part of actual blood, yet there are indications that it is the means of removing from the body something that is more injurious to it than a mere superfluity of the circulating fluid. A sudden suppression of the catamenia is frequently followed by symptoms of constitutional disturbance, which neither general nor local abstraction of blood suffices to relieve, and which are only abated

* Handbuch der Pathologischen Anatomie, tom. i. 583

* Bulletino delle Scienze Mediche, Apr. 1839.

by the restoration of the uterine flux, or by the establishment of a similar discharge from some other organ. Hence cases of *vicarious menstruation* may really be placed on the same footing with those of metastasis of secretion; and they serve to illustrate and establish the same general truth. Such cases are by no means uncommon, the menstrual flux being replaced by hæmorrhages from various parts of the skin, from the mucous membranes, or from glandular surfaces, especially the mammæ. The following case, quoted by M. Brierre de Boismont* from the "Médecine Pratique" of Pinel, is of peculiar interest from the variety of phenomena which it presents.

"Madlle A. had been subject, from the age of eleven, to attacks of hysteria, which were followed by vomiting of blood. She menstruated at fourteen; her health was re-established, and the catamenia continued to flow regularly for several months. A sudden fright suppressed the menses, and again hysteria came on. Vicarious menstruation now occurred. The legs swelled and were covered with vesicles, and during six months blood was regularly discharged from them. The left arm swelled, and the legs recovered; and for a year there was a regular sanguineous discharge from the arm. A third deviation occurred from the left thumb, which had been slightly wounded; the catamenia flowed from this opening for six months. In the fourth year two wounds were formed on the face from an attack of erysipelas; one, on the side of the nose, the other on the upper eyelid. For two years the periodic discharge took place from these openings, and it no longer occurred from the thumb. The abdomen in its turn was attacked with erysipelas, and for five months regularly there was a discharge from the navel at each menstrual period. For four months the discharge proceeded from the inner ankle of the left foot; for two months from the left ear; for three from the left nipple. When the discharge did not flow from any one part, bleedings at the nose and vomitings of blood took place, preceded by convulsions, pains in the head, and giddiness. After remaining some time at the Salpêtrière, the health of this young female improved, and regular menstruation was established."

It is probable that although the statement of Haller, already quoted, is universally true as a *possibility*, yet that it is practically verified only in the case of the excretions, the materials of which differ considerably from the nutritious elements of the blood, and accumulate in it when their usual exit-pipe is no longer open, forcing their way (so to speak) through other channels. If it be true, as we have suggested, that the materials of the *recrementitious secretions*, as they have been termed, are nothing else than the materials of the blood itself, slightly modified for their special purpose in the very act of elimination, we see why, when they are suspended, there is no accumulation of their materials in the circulating system, and no attempt at the separation of them by other organs.

* De la Menstruation considérée dans ses Rapports Physiologiques et Pathologiques.

Influence of the nervous system on the secreting process.—That the eliminating action of the various secreting organs, and the amount and nature of their products, are greatly influenced by the conditions of the nervous system, cannot be doubted by any one who takes a general survey of the facts of this department of physiology. For although we can no more increase, diminish, or otherwise alter any one of our secretions by a mere effort of the *will*, than we can, "by taking anxious thought, add one cubit unto our stature," yet there is ample evidence that the state of the *feelings* has a powerful influence upon many of them, increasing or diminishing their amount, or altering their character.*

A brief review of the phenomena which manifest this influence, will serve as the most appropriate foundation for an inquiry into its nature and extent.

The *mammary* secretion affords, perhaps, more remarkable evidence than any other, of the influence exercised over it by states of mind, in increasing or diminishing it, or in producing a complete change in its properties. Of the increase in the development of the gland at puberty, and still more during lactation, no definite explanation can be given; to say that it takes place by "sympathy" with the genital organs, being obviously a mere verbal evasion of the difficulty. But the activity of its function, when once it has been fully established, is mainly dependent upon the sensations and emotions connected with the act of suction, and with the thought of the offspring. Although the formation of milk may be constantly going on, yet it is greatly increased by the application of the infant to the breast. The quantity which can be squeezed from either breast at any one time, and the secretion of which may have occupied several hours, is about two ounces; and yet during a quarter of an hour's suction, an infant may draw three or four times that amount.

* True it is that there are cases in which secretions would seem to be *voluntarily* produced, as when real tears are shed by performers on the stage, in the personation of their assumed parts. But in such instances, a strict investigation of the mental state leads to the conclusion, that the emotions proper to the assumed character are for a time really felt; the effort of the will being rather exerted in the change of individuality (so to speak) than in the production of the several movements of gesture or expression which are significant of the mental state. And it is always observable that where the actor, possessing the requisite qualifications, *can* thus transform himself into the character he is personating, so that his tones, looks, and gestures shall be the spontaneous and natural expression of his temporary feelings, he produces a much greater influence upon the spectators, than he can do by the most careful voluntary realisation of his intellectual idea of the mode in which the character should be manifested. In these cases, then, as in all others, it is through the emotions, not directly by the will that the secretion is really excited.

When the child is applied to the breast, a sudden turgescence is experienced in the organ, known to nurses as "the draught:" this is probably due to an increased afflux of blood, produced by the mental state, as in ordinary blushing. The "draught" will often take place, and the secretion begin to flow spontaneously from the ducts, at the mere sight of the infant, or at the thought of him when absent, especially if this be associated with the idea of nursing. Analogous phenomena are observed in domesticated Mammalia. Thus a good milch-cow will yield far more at a single milking, than the udder could have contained, so that the secretion must have been rapidly formed during the process. There are certain breeds of cows which will only yield milk when their calves are in sight; and in some instances if a calf should die, its skin is placed over a living calf, the presence of which has the same effect. The most curious instances, however, of the power of irritation of the nipple and of mental emotions to excite the secretion, are those in which its production has long ceased, or has never taken place. Numerous cases are on record in which young women who have not borne children, and even old women past the period of child-bearing, have had such a copious flow of milk, as to be able to act as nurses. In all these instances, the flow appears to have been brought on, in the first instance, by the continued suction of the child, which had been applied to the breast to pacify it; or by the influence of strong mental emotions, or by both causes combined. It has been lately mentioned by Dr. Mc. William*, that the inhabitants of Bona Vista (one of the Cape de Verd islands) are accustomed to provide a wet nurse in cases of emergency, in the person of any woman who has once borne a child, and is still within the age of child-bearing, by continued fomentation of the mammæ with a decoction of the leaves of the *jatropha curcas*, and by suction of the nipple. Still more remarkable proofs of the same influence are furnished by the cases, of which several have now been narrated by credible witnesses, in which *males* have acted as efficient nurses.† The following, related by Dr. Dunglison‡, is one of the most recent and at the same time most satisfactory upon record; "Professor Hall, of the University of Maryland, exhibited to his obstetrical class, in the year 1837, a coloured man, fifty-five years of age, who had large, soft, well-formed mammæ, rather more conical than those of the female, and projecting fully seven inches from the chest; with perfect and large nipples. The glandular structure seemed to the touch to be exactly like that of the female. This man had officiated as wet nurse, for several years, in the family of his mistress; and he represented that the secretion of milk was induced by applying the children intrusted to his care to the breasts during the night. When the milk was no longer required, great difficulty was experienced in arresting the secretion. His genital organs were fully developed." Corresponding facts are also recorded of the male of several of the lower animals.

The secretion of milk may be entirely checked by mental emotions, especially those having reference to the offspring. Thus a mother sees her infant in sudden danger, either from illness or accident; the secretion is entirely suspended, and does not return until the child, having been restored to her safe and sound, is applied to the breast. The death of the infant will frequently occasion the sudden and complete cessation of the secretion. The same result will sometimes happen from powerful emotions unconnected with the infant: thus Sir A. Cooper mentions two instances in which the secretion, though previously abundant, was suddenly arrested by terror. It has been observed by medical men who practise much among the poor, that the apprehension of the brutal conduct of a drunken husband will put a stop for the time to the secretion of milk; the breast feels hard and knotted, and flaccid from the absence of the fluid; and some time elapses before the proper amount returns. It may be stated, generally, that whilst a tranquil, cheerful state of mind has a tendency to increase the secretion, the depressing emotions diminish it.

The mere increase or diminution of the secretion, from an influence communicated through the nerves, may possibly be accounted for by the influence they seem to exercise over the calibre of the smaller arteries, as shown in the act of blushing, to which "the draught" seems to have considerable resemblance. But no such explanation accounts for the important fact, that not only the quantity but the *quality* of the milk is changed by mental emotions. Grief, anxiety, fits of anger, or a continual fretfulness, tend to render the milk thin and serous, and to impart to it qualities that excite intestinal irritation, griping, and fever in the child that ingests it. It might be difficult to detect any noxious elements in it by chemical analysis; but the effect of the fluid upon the delicate system of the infant is a sure indication of their existence. With this knowledge, derived from almost daily observation, we can have no reasonable ground for refusing to credit accounts of still more remarkable results proceeding from the influence of mental emotion on the mammary secretion, such as the following:—"A carpenter fell into a quarrel with a soldier billeted in his house, and was set upon by the latter with his drawn sword. The wife of the carpenter at first trembled from fear and terror, and then suddenly threw herself furiously between the combatants, wrested the sword from the soldier's hand, broke it in pieces, and threw it away. During the tumult, some neighbours came in

* Report of the Niger Expedition.

† See the case described by the Bishop of Cork in Phil. Trans. vol. xli. p. 813.; one mentioned by Capt. Franklin (Narrative of a Journey to the Polar Sea, p. 157.); and one witnessed by Humboldt (Personal Narrative, vol. iii. p. 58.).

‡ Physiology, vol. ii. p. 417.

and separated the men. While in this state of strong excitement, the mother took up her child from the cradle, where it lay playing and in the most perfect health, never having had a moment's illness; she gave it the breast and in so doing sealed its fate. In a few minutes the infant left off sucking, became restless, panted, and sank dead upon its mother's bosom. The physician who was instantly called in, found the child lying in the cradle as if asleep, and with its features undisturbed; but all his resources were fruitless. It was irrecoverably gone."* Such a case might be regarded as a mere coincidence if it stood alone; but several others of similar character are upon record. Mr. Wardrop mentions † that having removed a small tumour from behind the ear of a mother, all went well until she fell into a violent passion, and the child being suckled soon afterwards, died in convulsions. He was sent for hastily to see another child in convulsions, after taking the breast of a nurse who had just been severely reprimanded; and he was informed by Sir Richard Croft that he had seen many similar instances. Burdach cites two cases of a similar kind; in one of which the infant put to the breast of its mother, just as she had received some very alarming intelligence, died in her arms before the eyes of the messenger; whilst in the other, the child having been nursed when the mind of the mother was in violent agitation, suddenly became extremely pale, and after some hours was attacked with paralysis on the right side, and convulsions on the left. Another of a very similar character has been more recently put on record. "A woman while suckling her child became violently excited by the loss of some article which had been stolen from her. She gave her child the breast while in a state of violent passion. The child at first rejected it, but subsequently took a quantity of milk. Soon afterwards violent vomiting supervened. In the course of some hours, the child took the other breast, when it was attacked with violent convulsions, and died in spite of medical aid." ‡

It will not be requisite to enter into similar details in regard to other secretions, the influence of emotional states on which is a familiar fact. Thus the flow of saliva is stimulated by the sight, the smell, the taste, or even by the idea, of food; whilst it may be entirely arrested by strong emotion, as is shown by the well known test often resorted to in India for the discovery of a thief among the servants of a family. All the parties being compelled to hold a certain quantity of rice in the mouth during a few minutes, the offender is generally distinguished by the comparative dryness of his mouthful at the end of the experiment. The gastric secretion is greatly influenced by the emotional states being usually increased by moderate exhilaration, and diminished by depression of the feelings. Any very strong emotion, however, usually suspends it for a time. The lachrymal secretion, which is continually being formed to a small extent for the purpose of bathing the surface of the eye, is poured out in great abundance under the moderate excitement of the emotions, either of joy, tenderness, or grief. It is checked, however, by violent emotions: hence in intense grief the tears do not flow. It is a well known proof of moderated sorrow when the flow returns: tears, however, do not bring relief, as commonly supposed, but they indicate that the violence of the emotion has passed off. The odoriferous secretion from the skin, which is much more powerful in some individuals than in others, is increased under the influence of certain mental emotions, such as fear or bashfulness, and commonly also by sexual desire.* That the formation of this secretion is due to changes occurring in the blood itself, and that the function of the cutaneous glandulæ is rather to eliminate than to produce it, would appear from the fact that the characteristic smell of different animals may be detected in their blood when it is treated with sulphuric acid. The influence of fear or of sexual desire on the odoriferous secretions of many of the lower animals is well known; the emission of a powerful and disgusting smell being not unfrequently a chief means of defence. The odoriferous matter is sometimes poured into the internal cavities, and discharged with the normal excretions, imparting to them its peculiar scent: thus the urine of a cat, voided under the influence of alarm, possesses a strong and disagreeable smell, which is with difficulty got rid of. The halitus from the lungs is in some persons so affected by mental emotions, that a piece of bad news shall almost instantaneously produce fœtid breath. A copious secretion of fœtid gas not unfrequently takes place in the intestinal canal, under the influence of any disturbing emotion; or the usual liquid secretions from its walls are similarly disordered. The tendency to defæcation, which is commonly excited under such circumstances, is not simply due therefore to relaxation of the sphincter ani, as commonly supposed, but is partly dependent on the unusually stimulating character of the fæces themselves. It is a prevalent, and, perhaps, not an ill-founded, opinion, that melancholy and jealousy have a tendency to increase the quantity, and to vitiate the quality, of the biliary fluid; and amongst the causes of jaundice are usually set down the indulgence of the depressing emotions, or an access

* Dr. A. Combe's Treatise on the Management of Infancy, p. 222., quoted from Dr. Von Ammon, "Die ersten Mutterpflichten und die erste Kinderspflege."

† Lancet, No. 516.

‡ Casper's Wochenschrift, 1845, S. 204.

* A series of glandulæ in the axillary region, bearing a general resemblance to the sudoriferous glands, but of larger size, have been supposed by Prof. Horner (Amer. Journ. of Med. Sci. Jan. 1846), and by M. Robin (Gaz. Med. Sept. 13. 1845), to be specially concerned in the elimination of the peculiar odoriferous secretion of this region. These glandulæ have been shown by Prof. Horner to be unusually large in the negro, whose axillary odour is peculiarly strong.

of sudden and violent passion. There can be no doubt, however, that a disordered state of the biliary secretion is frequently rather the cause than the consequence of a melancholic state of mind; the blood being sufficiently vitiated by a deficient elimination of bile, to have its due relations with the nervous system seriously disturbed, before any obvious indications of that deficiency make their appearance in the jaundiced aspect of the cutaneous surface.

These and similar phenomena afford clear proof of the influence exerted over the secreting processes by mental states; and it is scarcely to be imagined that this influence can be exerted through any other channel than the nervous system. If we further inquire to which division of the nervous system we are to attribute the conveyance of this influence, we shall find reason to regard it as chiefly, if not entirely, operating through the portion commonly known as the sympathetic. For there are many secreting organs which are supplied with no other nerves than those which they receive from this division, so that they cannot possess any connection with the cerebro-spinal centres except through its medium. The mammary glands, which are supplied by the spinal nerves as well as by the sympathetic, may be considered as requiring such a direct communication with the cerebro-spinal centres, inasmuch as their secretion is made, for obvious purposes, greatly dependent upon sensations directly affecting themselves, which is rarely the case elsewhere. The lachrymal and salivary glands would seem to have a more direct and exclusive connection than most others, with the cerebro-spinal centres; but perhaps this may be more apparent than real, for the fifth pair, from which they are supplied, seems in many respects to combine the attributes of a sympathetic with that of a proper cranial nerve; and bearing in mind the minuteness and the universality of the distribution of the sympathetic plexuses upon the trunks of the blood-vessels, we see that even these glands, like others, may be subjected to its influence.

If we further examine into the mode in which that influence is exerted, we shall, perhaps, find reason to attribute it to the effect of nervous agency, rather upon the walls of the blood-vessels and upon their contents, than upon the secreting structures themselves. For, as already remarked, the variations in the *quantity* of a secretion may be accounted for by such an increase or diminution in the access of blood as we know to take place, through an alteration in the calibre of the vessels, in the act of blushing or the paleness of fright; and the feelings experienced by the nursing female harmonise well with this supposition. On the other hand, the perversion of the *quality* of a secretion, which may take place as a result of mental emotion, would seem rather due to an alteration in the constituents of the blood previously to the elimination of the secretion, than to the exercise of any influence upon the secreting structure itself. For we find, in the case of the peculiar odorous matter for example, that it may be eliminated in a vaporous form by the air-passages, or by the intestinal canal; or that its taint may be imparted to the liquid secretions of the intestinal glandulæ; or, again, that it may be communicated to the urinary excretion: and this variety in the channels of escape of the same kind of material, pretty clearly indicates that it must have pre-existed in the blood. There are many other facts which confirm this view, by indicating that the condition of the blood whilst circulating in the vessels may be influenced by mental emotions, which probably act upon it through the medium of the sympathetic nerve; but of these it is scarcely the place to speak.

Another class of evidence, as to the exertion of an influence by the nervous system upon the secretory function, is furnished by observation of the results of the interruption of that influence, either by a diseased condition of the nervous centres or nerve trunks, or by experimental interference. One of the most familiar of these, on account of its frequent occurrence, is the change in the character of the urine in cases of paraplegia; resulting, as it would seem, from the secretion of an undue quantity of alkaline mucus from the lining of the bladder.* Various experiments have been made upon the nerves of the kidney, which seem to indicate that the normal secretion of urine is dependent upon their integrity. Thus Krimer† states, that division of any of the nerves of the kidney occasioned albumen and the red colouring matter of the blood to pass into the urine, their proportion increasing as that of the regular constituents of the urine diminished. Division of the vagus did not put a stop to the secretion of urine; but rhubarb and prussiate of potass taken by the mouth ceased to pass off by the urine, which at the same time acquired greater specific gravity from containing serum of the blood. After division of the spinal cord in the dorsal or lumbar region, the urine became limpid like water; and division of the sympathetic nerve in the neck caused it to become alkaline and albuminous. Brâchet and Müller have both experimented on the effects of the division of the sympathetic nerves which are distributed upon the renal artery. The former divided the trunk, and connected the divided ends by a canula, so as to allow of the continued passage of blood, whilst the nervous influence was completely intercepted; the latter produced the same condition by applying a ligature around the renal vessels, so tightly as to destroy the texture of the renal nerves at that point, and then relaxing it again, so as to permit the re-establishment of the circulation. In both cases the effect was similar; the secretion of true urine being interrupted, but a sanguineous fluid passing into the

* The nature of this change has been elsewhere considered. See Vol. III. p. 721 T. art. NERVOUS SYSTEM.

† Quoted in Müller's Physiology (Baly's Translation), p. 470.

ureter. Müller states that a remarkable softening of the kidney was always one of the results of these experiments.

Numerous experiments have been made to determine the degree of dependence of the secretion of the gastric fluid upon the nervi vagi; to these experiments copious references have elsewhere been given*, and we shall therefore only here allude to their results. The temporary suspension of the digestive process appears to be an invariable result of the complete division of the par vagum on both sides; and many of those who have witnessed this result have somewhat hastily concluded, that the secretion of gastric fluid is dependent upon nervous agency conveyed through that nerve. But it has been observed, in several instances, that the digestive powers have returned after a time, animals which were becoming much emaciated having recovered their flesh; and it is obvious, therefore, that the secretion of the gastric fluid *can not be dependent* upon the supply of nervous agency through the par vagum, as some have supposed it to be. It is true, that in a large proportion of the experiments made to determine this question, there has been no appearance of any return of the digestive power, after complete section of the par vagum on both sides; but there are various modes of accounting for this fact. The animals on which this experiment has been made, usually live for only a short time afterwards, on account of the disorder of the respiratory processes, which is one of the results of the operation; so that all which is proved by the great bulk of the experiments is, that the digestive process is generally arrested during the short time that the animal lives after the vagi have been divided or tied. And such negative results, as Dr. J. Reid has very justly observed, "can never overthrow the results derived from positive experiments, provided that these have been accurately performed, and are free from all sources of fallacy." †

With these facts before us, it is much to be desired that the experiments just cited, as to the influence of section of the renal nerves upon the secretion of the kidney, had been sufficiently prolonged to ascertain whether the effects described are transient, and whether the real secretion would be restored if time were permitted. And it is obvious that, as they at present stand, no such experiments can serve as an adequate foundation for the hypothesis entertained by some, that the act of secretion is dependent upon nervous influence, or, in other words, that nervous agency supplies a condition without which it cannot take place.

There is another group of phenomena bearing upon this question, though less closely related to it, — namely the changes in the state of *nutrition* in parts whose nerves have been injured, and which are thereby rendered insensible. The close affinity, however, already shown to exist between the functions of Nutrition and Secretion, is sufficient to make it apparent that they must stand upon the same footing in this respect, and that whatever is true as to the relation of either of them to the nervous system, must be true also of the other. Now it is an observation very frequently made, that parts whose nerves have been paralysed are peculiarly disposed to suffer from destructive inflammation, or to undergo a gradual wasting. The latter of these changes is easily accounted for on the general principle dwelt on under the head of NUTRITION, that the degree of nourishment which any organ or tissue receives, depends upon its functional activity; and thus not merely the muscles, but all the textures of a paralysed limb gradually waste away, the disuse of its muscles occasioning a stagnation in the circulation through the entire part. Of the former result it is necessary to make a careful examination, that we may be prepared to estimate it at its true value. One of the cases most frequently quoted in this connection, is the effect of section of the trigeminus in producing destructive inflammation of the eye-ball, as first shown by Magendie, and confirmed by many subsequent experimenters. A full account of these effects has been already given in another part of this work (see FIFTH PAIR), and it is therefore unnecessary to repeat them here. A corresponding result may be produced by disease. A case is related by Mr. Stanley*, in which there was impairment of the whole nutrition of one side of the face, with frequent attacks of erysipelatous inflammation, bleeding from the nose, central penetrating ulceration of the cornea, and, at last, destructive inflammation of the tunics of the eye, in consequence (as it would appear) of destruction of the trunk of the trigeminal nerve of that side by the pressure of a tumour near the pons. No such destructive effects ensue on section of any of the other cranial nerves; the only injurious influence exercised on the eye by any such operation, being the tendency to inflammation from irritants which the paralysed orbicularis palpebrarum does not shut out or help to remove. But, on the other hand, cases are occasionally to be met with (of which the author has himself witnessed more than one) of the complete paralysis of the ophthalmic division of the fifth pair, which has existed for some time without any other result than a degree of dryness of the surface of the eye from deficient secretion, and a disposition to superficial inflammation from irritating particles of whose presence no warning was given by sensation, and for whose removal there was consequently no provision. Such exceptional cases must be admitted as proving that, however unfavourable may be division or injury of the trigeminus to the continued healthy nutrition of the eye, still this *may* be maintained; and that it is consequently no more essentially dependent upon "nervous influence," supplied through that channel, than is the secretion of gastric fluid upon the

* Vol. III. p. 900. art. PAR VAGUM. † Ibid.

* Medical Gazette, vol. i. p. 531.

power supposed to be transmitted by the par vagum.

That the nutritive operations of other parts, however, are usually less vigorously and correctly performed when the nerves have been paralysed, than when they retain their entire integrity, would appear from numerous other facts, of which the following are examples. A case is related by Mr. Swan* in which a man's wrist having been injured by a cord having been very tightly drawn round it, there was partial paralysis of the hand, with constantly repeated ulcerations of its dorsal surface; and on amputation seven years afterwards, there was found to be induration of the median nerve, with adhesion of the tissues beneath the annular ligament. The following case, stated by Mr. Paget † on the authority of Mr. Hilton, is still more remarkable. "A man was at Guy's Hospital, who, in consequence of a fracture at the lower end of the radius, repaired by an excessive quantity of new bone, suffered compression of the median nerve. He had ulceration of the thumb, and fore and middle fingers, which had resisted various treatment, and was cured only by so binding the wrist, that the parts on the palmar aspect being relaxed, the pressure on the nerve was removed. So long as this was done, the ulcers became and remained well; but as soon as the man was allowed to use his hand, the pressure on the nerves was renewed, and the ulceration of the parts supplied by it returned."

That the reparative processes are affected, as well as those of ordinary nutrition, by the loss of nervous power, is a matter of familiar observation. A striking example to this effect is mentioned by Mr. Travers.‡ A man was rendered paraplegic by fracture of the lumbar vertebræ, the same accident having also fractured his humerus and his tibia. The former, in due time, united; the latter did not.

This peculiar affection of the nutritive processes appears rather dependent upon lesion of the sensory than of the motor nerves. Thus we have seen that the disorganisation of the eye after section of the fifth pair, takes place when only the sensory nerve of the part is affected, and that no such result occurs when only the motor nerves of the orbit are divided. In cases of disease or injuries of the spine, it has been noticed that sloughing of the bladder or other parts has occurred earlier and more extensively when sensation, than when motion alone, has been lost. And Mr. Curling has noticed § that two men having been taken at nearly the same time to the London Hospital with injury of the spine, one of whom had lost only the power of motion in the lower extremities, whilst the other had lost both motion and sensation, at the end of four months the atrophy of the lower extremities had advanced much further in the latter case than in the former. These phenomena would seem to harmonise with the view, that it is especially through the sympathetic system of fibres that the peculiar influence is exerted, whose continual agency we only recognise by the results of its withdrawal. For if, as already remarked, the fifth pair may be considered as the sympathetic of the head, the Gasserian ganglion may probably be regarded as belonging to the sympathetic system; and it has been observed by Magendie, and confirmed by Longet, that the destructive inflammation of the eye ensues more quickly after division of the trigeminal nerve in front of the Gasserian ganglion, than when the division is made between that ganglion and the brain. If this be true of the Gasserian ganglion, it is probably true, also, of the ganglia on the posterior roots of the spinal nerves; and thus the disordered nutrition which results from injury to the trunks of these nerves, and which is not to be accounted for by the mere disuse of parts, may be attributed, with some show of probability, to the interruption of the connection with the sympathetic system, which is specially established by these ganglia and their communicating cords. But it is to be remembered, on the other hand, that defective or disordered nutrition is a marked result of injuries of the spinal cord, whilst the sympathetic centres remain uninjured; and that general atrophy is a frequent consequence of chronic diseases of the brain. Fresh evidence is much required, therefore, to determine the relative shares of the cerebro-spinal and sympathetic centres, in regard to the influence exerted by them over the organic functions.

By the survey we have now taken, we are in some degree prepared to estimate the degree and nature of the influence exerted by the nervous system on the nutritive and secretory functions, and to inquire into the validity of the several doctrines which have been propounded on the subject:—

1. The first of these theories may be stated in the words of Dr. Wilson Philip, one of its most distinguished advocates:—"It appears," he says, "that the nervous influence is necessary to the function of secretion. It either bestows on the vessels the power of decomposing and recombining the elementary parts of the blood, or effects those changes by its direct operation on this fluid. From many facts stated or referred to in my inquiry, it appears that the vessels possess no powers but the muscular and elastic; and that the former, as well as the latter, is independent of the nervous system. Nor is it possible to conceive any modification of these powers by which they could become chemical agents, and thus be enabled to separate and recombine the elementary parts of the blood. The first of the above positions may, therefore, be regarded as set aside, and the necessary inference seems to be, that in the functions of secretion the vessels only convey the fluids to be operated on by the nervous influence." It will, perhaps, be sufficient to say of this hypothesis, that having been put forth at a

* On Diseases and Injuries of the Nerves, p. 60.

† Loc. cit.

‡ Further Inquiry concerning Constitutional Irritation, p. 436.

§ Med. Chirurg. Trans. vol. xx. p. 342.

time when the real nature of the secreting structure was altogether unknown, and when the choice seemed to lie only between the influence of the nerves and that of the vessels, it is totally fallacious now that a third agent has been discovered, to which all analogy would lead us to refer, at any rate, the chief instrumentality in the operation. The principal experiment adduced in support of this hypothesis, and of the identification attempted by Dr. Philip between nervous agency and galvanism, was the effect of section of the par vagum in checking the secretion of gastric fluid, and the renewal of the process under the influence of galvanism. We have already shown the utter invalidity of this result as a ground for any such inference; and it only remains to show the inconsistency and insufficiency of the hypothesis itself, which is easily done. For, as Dr. Prichard has justly remarked *, "if we begin by supposing the existence of the cause assigned, we shall find that there is one agent, namely the galvanic fluid, operating on one material, which is the blood, and effecting its decomposition. How, then, we may ask, does it happen that so many different substances are, in different examples of the same process, the results of this single operation? In other chemical decompositions, as when water is decompounded by the galvanic fluid, the result is the same and uniform. But in the instance supposed, the operation of the same chemical agents upon each other is followed by the formation of products of the most different descriptions: in one part of the vascular system the blood is converted into bile; in another, by the operation of the same chemical agent, into milk; in another, into tears." This variety of effects can only be explained by attributing them to the special endowments of the several secreting organs through which the nervous power is supposed to act; and if it be thus necessary to admit that such special endowments do exist, by which the particular nature of the secretion is determined, the question naturally arises, Of what use is the nervous power at all?

2. The second hypothesis, framed to meet this objection, supposes, to use the language of Prof. Müller, that "the influence of the nerves on the glands merely enables the secreting substance, in each gland, endowed with peculiar properties, to exert its chemical action." In order to sustain this hypothesis, it is necessary to show that the processes of secretion and nutrition are not only modified by the division of the nerves by which their organs are supplied, but that they are altogether suspended by that operation; the secreting or growing structures having no functional power of their own, save when connected with certain nervous centres, which are supposed to transmit to them the requisite vital force: much as in a factory there may be seen a great variety of machines, each of them constructed to perform a certain special action, but all of them dependent for their power of carrying it into effect upon a general motive power transmitted to each. We shall, perhaps, more conveniently and satisfactorily examine into the merits of this hypothesis, by bringing it into comparison with the next.

3. The third doctrine, of which Dr. Alison has been one of the most philosophical and consistent advocates, is to the effect that the whole organic or vegetative life of animals,— *i.e.* every thing which goes on in them without the intervention of any sensation or other mental act, including the functions of nutrition and secretion, — may go on without the intervention of the nervous system, and stands in no relation of *dependence* to any changes in nervous matter; but that these changes exert a powerful *controlling and modifying* influence on the organic functions, increasing or diminishing their activity, or even altering their character; just as, to use the appropriate illustration of Dr. John Reid, the movements of a horse are influenced by the hand and heel of the rider, although they are in themselves independent of him, being executed in virtue of the power inherent in the animal.

Now, in support of this last view of the subject, it may be urged, in the first place, that in one great division of the organised world, namely, in the vegetable kingdom, the functions of nutrition and secretion are performed, not only independently of, but without any kind of influence from, a nervous system; each act being the result of the properties inherent in the several parts of the structure itself, called into play by the appropriate stimuli. We should have a right to expect, therefore, that the corresponding functions in animals should be adequately performed by a similar mechanism; and it is fair, therefore, to throw the burthen of proof upon those who maintain the contrary. If we follow out in this case the great general principle of Cuvier, which every day's experience only shows to be more strictly correct and more widely applicable, — that the different classes of animals may be considered as so many experiments ready prepared for us by nature, who adds to or takes from their several organs, just as we might wish to do in our laboratories, showing us at the same time the various results of these combinations,—we see that a comparison of different organisms affords us a much better ground for the determination of this question, than can be obtained from the results of such experiments as have been already cited; it not being possible to make such experiments, without such injury to the organism as is of itself a serious disturbing cause. We notice, on looking at the highest animal, that the organic functions are brought into very close relation with the animal powers, and are liable to be considerably modified by the exercise of the latter. But, as we descend the scale, we find the nervous system constituting a less and less predominant part of the organism, and the apparatus of organic life becoming more and

* Review of the Doctrine of a Vital Principle, p. 198.

more disconnected from it; until, in zoophytes, we are scarcely able to distinguish a nervous system at all, whilst all the operations of growth, nutrition, and secretion take place very much as in plants, in which no nervous system exists. Thus we find that "the nervous system lives and grows within an animal, somewhat as a parasitic plant does in a vegetable," deriving its nutriment from the structure in the midst of which it is developed, and capable of exercising a certain action upon it, but being strictly a *superadded* part, and having rather an *adaptive* than an *essential* connection with that structure.

Now this view has derived from late discoveries in minute anatomy, as complete a confirmation as any such facts are capable of affording. For it has been shown, not merely that the functions of nutrition and secretion are common to animals and plants, but that the component elements of the organs by which they are performed are in both instances essentially the same. We have seen that the act of secretion is effected, even in the most complex gland, by the agency of aggregations of cells, each of which lives for and by itself, and appears to be dependent upon no other external conditions, than those which are required for the growth of the simplest cellular plant, namely, food and warmth. And it is difficult to conceive how, over that most essential part of the secreting process — the developement of the secreting cells — the nervous system *can* exert any direct influence.

Another natural experiment, whose immediate bearing is rather upon the physiology of nutrition than upon that of secretion, but which is really as conclusive in regard to the latter as the former, is exhibited to us in the early growth and developement of the embryonic structure; which makes considerable progress, especially in invertebrated animals, before any trace of the nervous system can be detected. And in the human species the case is not unfrequent, of the fœtus coming to its full size with the usual variety of textures in its composition, but without either brain or spinal cord. It has been said, however, that in such instances the ganglia of the sympathetic system probably exist, and supply the influence supposed to be needed; but there are cases on record, in which these would seem to have been carefully looked for and not detected.* And moreover, even if their uniform presence were to be admitted, and the power of sustaining the operations of nutrition and secretion be supposed to reside in them, how are we to explain the effects of injuries of the brain and spinal cord, the ganglionic centres being left intact? We can see no other consistent account of these phenomena, than that which is presented by the last of the three hypotheses enumerated; the functions of nutrition and secretion (like the contractility of muscular fibre) not being regarded as dependent for their ordinary exercise upon any power supplied by the nervous system, but being considered to be modified by causes operating through it.

And that this is the true view of the matter, would further appear from a careful examination into the nature of the phenomena which follow the section or injury of nerve-trunks or centres, and which have been supposed to indicate the impossibility of the continuance of true nutritive operations after the withdrawal of the hypothetical nervous influence. In the first place, the effect produced by section of those nerves which are supposed to exert the greatest influence, is probably not in any case a simple suspension of the nutritive operations, nor a death of the part; but it is of the nature of inflammatory action, involving disordered nutrition and perverted secretion. Further, this disordered condition does not seem to be the direct result of the paralysis of the nerves, so much as an indirect consequence of the want of power to resist morbific causes. "If the section of the sensitive nerves of a part," it has been observed (with special reference to the inflammations of the eye, the lungs, and stomach, consequent upon section of the fifth pair and par vagum), "were the direct cause of its inflammation, we should expect to see inflammation in all parts of which the sensitive nerves are cut; whereas the phenomenon in question is seen only in a few parts; and in those parts it originates, and is chiefly seated, in a single texture, viz. the mucous membrane: that membrane is distinguished from others in the body by its power of bearing the contact of air, of foreign substances, and of excretions elaborated within the body, with impunity. This power seems obviously connected with its vital power of throwing out, when irritated, a mucous secretion, which protects it equally as the cuticle protects the true skin; and this adaptation of the quantity of protecting mucus to the irritation which may act on a mucous membrane, may be very naturally supposed to depend on its sensibility, and to cease when its sensitive nerves are divided, and allow the mucous membrane to inflame and slough, equally as a serous membrane would do from the irritations which, in the natural state, excite only a healthy action upon it. On this supposition, the inflammations in question depend, not simply and directly on the division of nerves, but on the action of the air, the food, the bile, &c., on mucous membranes deprived of their sensibility, and thereby in great measure of their protecting mucus; and bear an analogy to the inflammations of the same membranes which frequently take place from deficiency of the mucous secretion, in cases of death by starvation, and towards the close of lingering and exhausting diseases."* And lastly, even supposing the inflammatory changes to be the direct result of the paralysed state of the nerves, they in themselves afford conclusive evidence against the doctrine, that the nervous influence is essential to the nutritive and

* Elber, de Acephalis, pp. 31. 35. 45.

* Brit. and For. Med. Rev. vol. iii. p. 14.

secretory operations; for, as Bichat observed, respecting the inflammation and suppuration of the testicle after its complete isolation from the larger masses of the nervous system, the establishment and maintenance of a morbid secretion was just as conclusive evidence of the independent character of the process, as if the normal product of the testis had been continued.*

Upon all these grounds we feel justified in asserting, that no adequate ground has yet been furnished by pathological observation and experiment, for the establishment of any other doctrine as to the relation between the nervous system and the organic functions, than the last of those just stated. It is perfectly conformable to the facts supplied by comparative physiology, and by the history of developement; and may be said to rest upon them as upon a broad foundation. It harmonises sufficiently well with the results of experiment and pathological observation on man and the higher animals, to be considered as giving the most satisfactory interpretation of them which, in the present state of our knowledge, seems likely to be attained; and if it be not the whole truth, is evidently not far from it. On the other hand, the doctrine that nervous influence is essential to the performance of the nutritive and secretory operations, is opposed to the mass of phenomena presented in the vegetable world, in the lower tribes of the animal creation, and in the history of the developement of the higher; to the exact knowledge we now possess of the structure of glands themselves; and even to the results of those experiments and pathological observations which have been relied upon to prove it, when these are carefully sifted. (*W. B. Carpenter.*)

* Anatomie Générale, tom. iv. p. 604.

SEMEN. — *Sperma; Sperm*, Engl.; Gr. σπερμα; Germ. *Samen;* Fr. *Sperme.* — Male animals, when perfectly developed and capable of procreation, secrete a thickish white fluid in their testicles, which possesses the faculty of inciting the generative parts of corresponding female individuals to a series of processes, the ultimate result of which is the developement of the embryo. This fluid, so indispensably necessary as the medium of sexual generation, is the seed or semen.

Histological elements of the semen. — Microscopic analysis proves that the most essential morphological constituent of the semen consists in the *spermatozoa* (animalcula spermatica), a number of corporeal elements, distinguished by their specific shape, and by their peculiar phenomena of vitality. The attention of physiologists and others has been actively directed towards them, ever since their discovery by *Ham* and *Leuwenhoëk;* and the most varied and frequently the wildest assumptions and conjectures have been occasioned in consequence. In spite of the intimate relation which they evidently occupy with regard to the procreative capacity of the semen, they have been considered, even up to the most recent period, as independent animal organizations, or parasitical animals. The reason adduced for such a conjecture is the peculiar motion which may be observed in almost all of these formations, and which in many cases bears a striking resemblance to voluntary motion. This assumption, however, is perfectly irreconcileable with our present knowledge of the quality and developement of these bodies, based as it is principally upon the discoveries of *R. Wagner*, *Von Siebold*, and *Kölliker*.

With our present means of a scientific diagnosis, it can be proved that the formations in question are mere elementary constituents of the animal organization, like the ova, constituents equally as necessary for the spermatic fluid as the blood-globules are for the blood. The remarkable phenomena of the life of spermatozoa are quite analogous to those phenomena of motion observable not only in animal formations, but also in vegetable structures; as, for instance, in the spores of the algæ and of the lower species of fungi, in the so termed vibriones, which grow out into the fibres of the conferva called "hygrogrocis."

The denomination of "animalcula spermatica, spermatozoa," is based upon the assumption that these moveable elements of the semen are animated organizations endowed with all the attributes of animals; and they were, accordingly, classified among the Infusoria or Helminthea. *Kölliker**, the first who most distinctly expressed the assertion that the so called spermatozoa are mere elementary parts of the organization, mere histological elements, applied to them the name of *fila spermatica;* a designation which would certainly be appropriate, if all the formations in question possessed a linear form. *V. Siebold*†, rejecting the old name on the same grounds, has proposed that of *spermatozoides*, which, however, we consider as still less happily chosen. We confess that we cannot exactly see the necessity of creating a new designation for these spermatic elements at all, the less so as many names in our scientific nomenclature specify something quite different from that which they immediately indicate. We shall therefore principally use for the future the old name of spermatozoa, admitting at the same time that it is not quite a suitable one, and that it might probably be better expressed by the designation of corpuscula seminis, or spermatococci, by which they have occasionally been distinguished.

The spermatozoa, or corpuscula seminis, are not merely normal, but in fact the essential constituents of the procreative semen. Indeed, it appears, in many cases, especially among the lower animals, that they are its only constituents. The presence of a fluid, *liquor seminis*, to hold them in sus-

* Beiträge zur Kenntniss der Geschlechtsverhältnissen und der Samenflüssigkeit wirbellosen Thiere. Berlin, 1841.

† Uber die Spermatozooiden der Locustinen. From the Acta Acad. Leop. Carol. Nat. Cur. vol. xxi. Part I. S. 1.

pension, is not perceptible in these cases; and it would be perfectly unnecessary, when procreation takes place, without sexual connexion, in the water. The presence of such a medium can certainly not be denied among the vertebrata; but it remains to be proved whether it is of specific importance to the semen, or whether it does not perform a subordinate part both in a histological and physiological point of view. It is not quite improbable that the presence of this liquor seminis is merely incidental, and that it stands in a certain connexion with the process of developement *, and perhaps also with the formation of the spermatozoa. In a physiological point of view, it may perhaps serve as the medium of a more easy and safe transmission of the spermatozoa to the ovaries. It may form for the spermatozoa a medium, which serves partly for the better developement of their peculiar motions, and partly to afford them an immediate protection against the external influence of many injurious agencies.

At any rate, the liquor seminis appears to be much more an accessory product of secretion in the glandular elements of the testicles than a necessary and essential constituent of the semen. A comparison with the liquor sanguinis would therefore not be applicable. We would rather draw attention to the fact that a peculiar fluid is also secreted in the female generative organs. For instance, among the mammalia the fluid contents in the Graafian follicles, which, taking it in all its bearings, we feel inclined to consider as analogous to the liquor seminis.

The liquor seminis, wherever it occurs, exhibits itself as a homogeneous, transparent fluid, existing always only in a small quantity. It is frequently only observed after the addition of a re-agent, as acetic acid and alcohol, when it coagulates and forms a fine, delicate, granular matter betwixt the spermatozoa.

Formerly, one of the authors of this article, *R. Wagner*, distinguished, in addition to the spermatozoa, other particular globular formations †, which he called *granula seminis*, and which he considered at that time as independent elements. At the present moment, however, it may be looked upon as decided that these formations occupy a relation of developement (*genetischen Beziehung*) to the spermatozoa ‡, being, in fact, the vesicular elements which have since been generally acknowledged as the formative cells of the spermatozoa. The former opinion of *R. Wagner*, at a time when the formative processes of the spermatozoa was so little known, was apparently justified by the circumstance that these bodies are found not merely in the testicles, but likewise in the vasa deferentia. This fact is even at the present moment of great interest. It proves that the developing cells of the testicles are not all of them used for the production of the spermatozoa, but that a number of them are removed in their primitive state, such removal being either accidental, or caused by their incapability of a further developement.

We need not enter here into other irregular and fluctuating constituents of the semen. They are principally found only in the duct of the generative organs, and generally consist of fatty globules, of several epithelial cells, &c., which, from their characteristic appearance, are readily perceived to be incidental admixtures.

Periodical developement of the spermatozoa and testicles.—The developement of the spermatozoa in the interior of the testicles does not take place constantly and uniformly during the whole of life; but a genuine semen, with its characteristic histological elements and physical peculiarities, is only secreted at the period of sexual maturity, and then only during the period of rutting. It is likewise only at this period that the semen is capable of acting with fructifying influence upon the female organs of reception. In those cases where the periods of rutting repeatedly occur in one year, where, as in human beings, and among most of the domestic animals, they are hardly separated by any perceptible or distinct intervals, the spermatozoa are certainly found at all times from the period of puberty thoughout life. But even in these cases it may be assumed that the production of the spermatozoa is principally confined to the respective periods of rutting, although not perhaps entirely limited to it.

The spermatozoa, like all other elementary constituents of the animal body, are likewise subjected to a process of re-formation (*Ruckbildungs-process*), if they do not make their exit from the body. If the periods of rutting are separated from each other by longer intervals, this process affects likewise the organs for the transmission and for the preparation of the liquor seminis. The testicles and vasa deferentia in these cases decrease considerably in size and developement until the commencement of a new sexual period leads them towards a new state of turgescency, and anew capacitates them for the production of spermatozoa.

The period of rutting among most animals, at least in our climate, is associated with the commencement of the warmer season. The testicles then receive a larger influx of blood; they increase in size; the walls of the spermatic canals become thicker, their lumina larger. These changes of the generative organs

* This modifies or changes the view respecting the function of the liquor seminis, which was formerly entertained. See Rudolph Wagner's Elements of Physiology; translated by Robert Willis. Part I. p. 74. 3d German edition, S. 53.

† Fragmente zur Physiologie der Zeugung, p. 29., in the Transactions of the Math. Physical Class of the Royal Bavarian Academy of Science, Munich, 1837. Lehrbuch der Physiol. 3d edition, S. 13. English edition by Willis, p. 5.

‡ Stein likewise is at present of this opinion. (Vergleich. Anat. und Phys. der Insekt. S. 107.) after having previously represented these formations in the shape of a peculiar theory of procreation.

may be most readily traced among birds, the increase of size of the testicles being very striking with them at the period of copulation, as proved by the researches of Hunter, as quoted by Owen*, to which we may add our own, which likewise have been instituted with the sparrow.

During the winter the testieles only possess a very small size. In a specimen which we examined in the middle of January, they scarcely measured a millimeter. Both testicles were equally developed, had a globular shape, and weighed together (in a fresh state) about 3 milligrammes. The vasa deferentia, which we were only enabled to discover after a very accurate examination, appeared in the shape of a couple of thin and almost solid strings. Henceforward the testicles and spermatic ducts begin to grow, although at first but very slowly. The increase of the testicles does not however extend itself in all directions. It is limited principally to the longitudinal diameter, thus causing the subsequent kidney form of these parts. Towards the end of the month of January they reach the length of about $1\frac{1}{2}$ Mm., whilst the transverse diameter is not materially ehanged; weight of both testicles $=4$ Mgrs. In the middle of February the length reached about 2 Mm., the width $1\frac{1}{3}$, the weight 6 Mgrs. By the end of the month the organ enlarges itself to a body of $2\frac{1}{4}$ Mm. in length, $1\frac{2}{3}$ Mm. in width, with a weight of 8 Mgrs. At the commencement of the next month the testicles measured $2\frac{1}{2}$ Mm. in length, 2 Mm. in width. They had a weight of 15 Mgrs., which increased at the middle of the same month to 48 Mgrs., the length simultaneously increasing to $3\frac{1}{2}$ Mm., the width to $2\frac{2}{3}$. The subsequent developement of the testicles is much more rapid and extensive. At the commencement of April we found them to be of a considerable size, with a longitudinal diameter of 8 Mm., a width of almost 7 Mm. The weight, we are sorry to say, we did not note down. The microscopical analysis now for the first time exhibited to our view spermatozoa in the different stages of developement. The former stages of developement had not been capable of producing such formations.

The testicles obtain their perfect developement towards the end of this month (April), when they measure 10 Mm. in length, with a width of 8 Mm., and a weight of nearly $\frac{2}{3}$ Gramme (0.575 Gramme.).

The researches which we have now eommunicated are of course only of an average value or validity, and cannot be applied to all individual cases. Deviations from them are therefore by no means rare. Individual speeimens exhibit either a very premature or a very late developement. Thus we met with, for instance, as early as the middle of January, specimens, the testicles of which had a length of 2 Mm., a width of $1\frac{1}{2}$, and a weight of 6 Mgrs., such occurring usually only four weeks afterwards. Towards the end of the same month the testicles of another individual measured a length of $2\frac{1}{2}$, a width of 2 Mm. As an opposite instanoe, we may mention that we found at the end of the month of February, in the testicles of a sparrow, a length of $1\frac{1}{2}$ Mm., a width of 1 Mm.

* Vol. I. p. 354. art. Aves.

Form and history of developement of the spermatozoa. — The first thing that strikes the observer, on entering into a microscopical research of the semen of a great number of animals, is the difference of the shape of the spermatozoa. The specifie shape of these elements generally corresponds with the individual classes, genera, and species, and this so distinctly, that one may often safely venture to infer from it the systematic position and the name of the animals investigated. We will not, however, venture to determine whether this variety of the shape is connected with the rich variety of animal formations, or whether the specific shape of the spermatozoa has a determining influence upon the developement of the germ into a certain specific form. Such a conjecture, however, would certainly not be supported by the circumstanee that a corresponding shape of the spermatozoa is frequently met with in animals very far removed, indeed quite different, from each other. The variety of form in the spermatie elements is the more striking, because the female generative elements, throughout the animal creation, are distinguished by a uniform developement.

Most of the spermatozoa have a slender, linear body, either filiform throughout, or swollen and enlarged at one end, which for convenience we designate the anterior end. This swollen extremity is differently developed, and frequently grown into a peculiar independent part, as, for instance, into a head or body, from which the other thin and longer part is extended as a whip-like tail. Various other forms of the spermatozoa cannot, however, well be reduced to this type, or at least only by the assumption that the filiform body is abridged in its longitudinal axis, to compensate for which it afterwards increases much in width and thickness. Henee the short dense thick corpuscles of a different shape, which are occasionally found in the genuine semen instead of the filiform spermatozoa. The size of the spermatozoa, like the size of all the elementary constituents of the animal body, is only very slight. It is only in a few cases that it exceeds the length of a line, a much shorter dimension being however much more general.

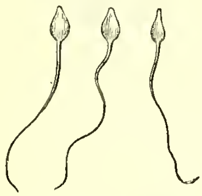
Let us now trace the different histological formations of the semen, according to form and connexion in the principal groups in the animal creation.

Man. — In man (in which the spermatozoa (*fig.* 323.) are eomposed of head and tail), as indeed generally in the whole division of the Vertebrata, the size * does not often amount to more than $\frac{1}{50}'''$, at the outside $\frac{1}{40}'''$.

* We always refer in our measurements to Parisian lines; a millim. = 0.443 of a Paris line.

Of this by far the greatest part is occupied by the filiform tail. For the anterior body there hardly remains more than $\frac{1}{800}'''$ to $\frac{1}{600}'''$. The body is rather flattened on the sides, so as to represent the shape of an almond. Viewing it from the surface (*fig.* 323. A), it looks like an oval disc, the longitudinal diameter of which exceeds the greatest width by

Fig. 323.



A B

Spermatozoa of Man.

A, viewed on the surface; B, viewed edgeways.

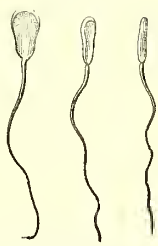
about one half, and which extends itself towards the posterior part into the filiform caudal appendix. The anterior extremity of the body is usually rather pointed, almost like the lower part of a pear or the point of an egg. If the body is situated on its edge (*fig.* 323. B), it resembles a short rod, rather pointed towards the anterior part, the transverse diameter of which measures about from one half to one third of the greatest transverse diameter of the lateral surface. The tail is cylindrical, thin at the posterior part, and prolonged into a very fine point, which can only be perceived by the application of the highest magnifying power. At its anterior part, on the other hand, the double outline can distinctly be traced. But the thickness even here is always less than the thickness of the body.

Mammalia.—The spermatozoa of the Mammalia have quite a similar form, but frequently a more considerable size. The genus Mus, the smallest mammals, remarkable to state, are distinguished in the latter respect. The length in Mus decumanus amounts to $\frac{1}{12}'''$, in Mus musculus $\frac{1}{20}'''$, in Hypudacus arvalis, Sciurus, Talpa $\frac{1}{25}'''$, in Plecotus auritus, Cercopithecus ruber $\frac{1}{30}'''$. In many other cases,—in Canis, Felis, Erinaceus, Lepus, Cervus, &c., the length of the seminal fibres is about the same as in man. But even then the body is generally of a considerable size; as, for instance, in Sciurus, Cervus, and Lepus, where it measures $\frac{1}{250}'''$, as also in Talpa. The size of the body in a rat amounts even to $\frac{1}{150}'''$. The difference, however, is frequently less considerable. In Canis, Rhinolophus, Hypudacus, Mus musculus, &c., the body only measures $\frac{1}{400}'''$, and even still less in the horse and cat.

The form of the body varies extremely *; all, however, exhibit parts corresponding to those of the spermatozoa of man. The fundamental form likewise is always that of a flattened oval. The spermatozoa of the monkey tribe are very similar to those of man; likewise those of the cat, in which the body has a similar inverted oval shape; as also those of the hedgehog. The body of the spermatozoa in the mole, as also in the horse, is uniformly rounded off at both extremities. In the Rhinolophus it presents the same regular form, but at its anterior extremity it seems to be furnished with a short and thin appendix, resembling a point. In other mammalia the posterior extremity of the body, which is in connexion with the tail, is the narrower one, whilst the free anterior end appears to be rounded off, or even to be more or less flattened. If the anterior extremity decreases gradually, the body assumes the usual egg form (Cervus, Lepus), whilst it exhibits more the shape of a pear in cases where that extremity is rounded off (Canis, Sciurus).

The width of the body, as well as the lateral flattening off, likewise increases with the enlargement of the longitudinal diameter. Its extreme developement is reached, as it seems, in Sciurus (*fig.* 324.). Here the body is very

Fig. 324.



Spermatozoa of the Squirrel (Sciurus vulgaris).

Viewed in different aspects.

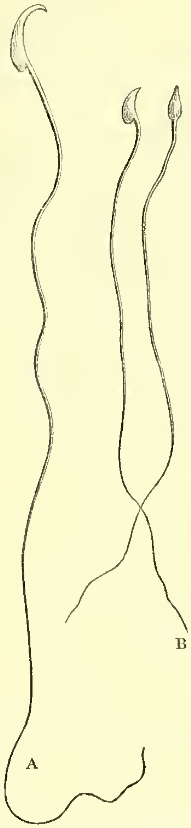
expanded and thin, like a fine, transparent leaf. The lateral surfaces are hollowed out, like a spoon, or shovel. The margins, or edges, however, do not participate in this. They appear, especially at the anterior end, much thickened.

Another very remarkable form is seen in the body of the spermatozoa of the Muridæ. It is attached to the anterior end of the caudal appendix, like the blade of a knife, but in such a manner that the tail, when viewing the body on the surface, is not situated as usual in the central longitudinal axis of the body, but passes over into one of the lateral margins. It might almost give rise to the conjecture that the one lateral half of the body had arrived at its full developement, whilst the other had dwindled away and been lost. In fact, the whole appearance of the body seems to justify the assumption of such a non-symmetrical kind of developement. At the point which usually corresponds to the centre of the body, the lateral part, distinguished by its thickness, is prolonged into the tail. The thickness gradually decreases towards the upper extremity, which is bent in an arched manner, presenting a convexity towards that

* Vid. R. Wagner's Icon. Physiolog. Table I. Elements of Physiology, p. 13.

margin of the body which projects at the posterior part into an obtuse angle. In the rat (*fig.* 325. A) the body is very long, but narrow in proportion, and bent like

Fig. 325.



A. *Spermatozoa of the Rat*; B, *of the common Mouse.*

a sabre at the anterior extremity. The body of the spermatozoa of the domestic mouse is shorter, and may be compared to a bent bistoury. The anterior end, however, is likewise drawn out into a short point, which in the field mouse is very slightly developed. The differences in the caudal appendages of the spermatozoa among the mammalia may be reduced to mere differences in length and thickness. In all of them the anterior part attached to the body distinguishes itself from the posterior part by its thickness, but not always to the same extent. Wherever the spermatozoa distinguish themselves by their length, the tail is likewise proportionably thick.

Dujardin* occasionally observed in the spermatozoa of men, at the commencement of the tail part, a small irregularly shaped protuberance, which *Kölliker* (who had likewise observed this in the semen of rabbits) supposes to be a mere temporary phenomenon — only a phenomenon of developement —and that it subsequently disappears, whilst its adhesive matter is expended in the prolongation of the tail. This assumption likewise appears to us possible, although it is remarkable that such swellings or protuberances are so rarely met with, and, therefore, certainly cannot be considered as constant associates of the developement. We have only observed a few cases of this description, and that principally in the semen of rabbits. The swellings, which in their physical condition, especially in their refracting power, coincide entirely with the anterior body, have generally a globular shape, but exhibit otherwise many differences in size and position. They are found sometimes at the commencement of the tail part, sometimes rather remote from it. It appeared to us as if the respective appendages were formed less by a swelling of the tail fibre, than by a peculiar enclosing matter. It seemed to us, at least in a single spermatozoon, as if the tail could be clearly distinguished in the interior like a peculiar fibre. Further investigations on this subject are still necessary.

The spermatozoa of the mammalia generally lie very irregularly and confusedly. At times, however, they are grouped together (as we have especially found in the rat, the guinea pig, and rabbit, and as others have likewise observed in men) in very regular fascicles or bundles, which are formed by the bodies of the spermatozoa adhering by their lateral surfaces, as may be often observed with the blood globules.* It is uncertain, however, whether this group-like association of the spermatozoa is dependent, like that of the blood globules, on definite physical processes.

The *developement* of the spermatozoa takes place among the mammalia in the interior of vesicle-shaped globules, which fill up the separate little canals of the testicles in great quantity. *Kölliker* has traced this mode of developement first of all in the guinea pig (which is very convenient for these investigations); likewise in the domestic mouse; but has subsequently, after more extensive researches, determined that the mode of developement in all the mammalia is the same. These developing vesicles have pretty uniformly a size of about $\frac{1}{200}'''$, but intermixed with them there are frequently found vesicles of a smaller and of a larger diameter (to $\frac{1}{170}'''$). Taken from a fresh dead body, and when examined without being treated with water or any other agent, they are as clear as glass, possessing a delicate contour, and perfectly homogeneous contents. The latter, however, coagulates very readily, assuming thereby a granular quality; but this we cannot consider as its natural condition.

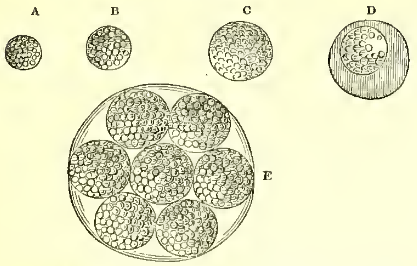
Most of these vesicles are free within the little seminal canals (*fig.* 326. A, B, C). They are frequently surrounded by a cellular enclosure,

* Annal. des Sciences, 1837, t. vii. p. 291.

* Vide Wagner, Icones Physiolog. tab. I. *fig.* 2. Elements of Physiology, p. 10. *fig.* 4.

either singly (*fig.* 326. D) or in numbers of three four, six, or seven (*fig.* 326. E). A more considerable number of them in one common cyst is unusual; but they may, according to *Kölliker's* statement, amount to twenty. The size of the cyst naturally depends on the number and state of developement of the vesicles it encloses. Ordinarily it amounts to about $\frac{1}{100}'''$—$\frac{1}{80}'''$.

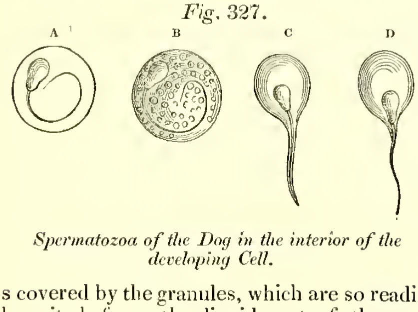
Fig. 326.



Developing Vesicles of the Spermatozoa from the Testicles of the Dog.

On pursuing the genesis of the vesicles of developement, it will be found that they are produced in the interior of cells, according to the law of endogenous formation. The various circumstances which present themselves during the microscopical analysis support the probability of this opinion. It is certainly often difficult to determine whether an individual vesicle is destined for the production of other cells (tochter-Zellen), or immediately for the formation of a spermatozoon. But we shall see presently that the daughter cells are furnished with the same capacities as the free vesicles of developement; they are like them in every respect, and justify the inference of a perfect identity with them. Wherever, therefore, we find these free vesicles of developement, they have, in our opinion, likewise been produced in the interior of other cellular formations, and have only become free by the dissolution of the former. The real process of formation of the spermatozoa in the interior of the vesicles of developement cannot be reached by our observation. The spermatozoon does not possess at its commencement those sharp, distinct contours—that great refracting power, which afterwards so much distinguish it. Like a slight linear shadow it is seen lying in the interior (*fig.* 327. A, B); in addition to which it is covered by the granules, which are so readily deposited from the liquid part of the contents. It is only gradually that it assumes a distinct appearance. At first the body only is seen, being recognisable by its specific form. The tail becomes visible subsequently. The entire spermatozoon lies in a curved shape close to the wall of the vesicle, until it has reached its full developement, when it becomes free by the bursting of the vesicle of developement. Sometimes (*fig.* 327. C, D) individual vesicles may be seen, from which the tail of a spermatozoon is projecting, whilst the body is still situated in the interior. The vesicle of developement generally retains, however, its original round shape, even when the spermatozoon has reached its perfect developement, and begins to stretch itself. Angular vesicles of developement, which occur so frequently in other animals, probably never occur here. It is only in rare cases (*fig.* 327. D) that the vesicle extends itself into a thin tail-like appendix, which then encloses the posterior part of a spermatozoon, and which is evidently only produced by the stretching of the latter. A law, which *Kölliker* first pronounced as correct, may here be enumerated, viz. that only one single spermatozoon, and never a greater number, is developed in each vesicle of developement.

Fig. 327.



Spermatozoa of the Dog in the interior of the developing Cell.

The formation of the spermatozoa takes place in exactly the same way in the vesicles of developement, even in those cases where the latter have not become free, but remained enveloped by their mother cells. The spermatozoa, in this case, are not, however, immediately set free by the dissolution of the vesicles of developement; but they arrive, first of all, in the cavity of the external cyst. The number of the enclosed spermatozoa therefore depends on the number of the enclosed vesicles of developement, a single fibre only being formed in each vesicle. The presence of several spermatozoa in the interior of a vesicle, therefore, affords us an immediate proof, that the latter histologically possesses the function of a mother cell, and is not itself the vesicle of developement.

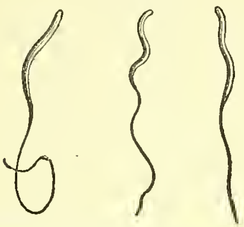
But likewise in this case the process terminates with the dissolution of the cyst that surrounds the spermatozoa, and which prevented their becoming free immediately after the dissolution of the vesicle of developement.

According to analogy with other animals, it is very probable that the above mentioned association of groups of the spermatozoa into fascicles is caused by the longer persistency of the vesicles of developement in the interior of a common mother cell. At all events, such an occurrence is traceable in almost all other cases in which a similar association in groups takes place; and it also happens among the mammalia, to judge from the fact, that a delicate cyst-like enclosure is often perceived at the circumference of the bundles.

Aves. — The spermatozoa of birds possess uniformly, instead of the short oval and flattened body which distinguishes them in mammalia, a body of a long and slender

shape, which gradually passes off into the posterior tail-like portion. The body, in most birds prolonged into a cylinder, is distin-

Fig. 328.



Spermatozoa of the Cock (Gallus domesticus).

guished by a greater thickness from the thin and filiform tail, which is twice its length (*fig.* 328.). In other instances, however, it makes a number of spiral twists, generally four, which make it look like a corkscrew. The anterior end, in that case, is generally pointed, and the posterior end is gradually extended into a long and straight tail (*fig.* 329.). The latter form is generally peculiar to the singing birds, and, indeed, an exclusive characteristic of them, enabling us, even by this circumstance, to detect the Picarii of *Nitzsch* from the true birds of song. Birds of the genera Coracias, Caprimulgus, Alcedo, at all events, show this corkscrew form as little as those of the genera Cuculus, Picus, &c.; whilst the birds of the raven tribe exhibit this same characteristic in common with the singing birds.

Fig. 329.

Spermatozoon of Fringilla Spinus.

The number of separate twistings or turnings of the body, and their distance from each other, is different, however, in the several families and genera of singing birds. Among the thrushes, for instance, the spiral is very extended, and almost undulating, whilst the numerous twinings pass into one another at an obtuse angle. The twistings are less in number (from 4 to 5), in the Lanius (the *Shrike*); they are very narrow, and almost acutely angular, whilst they are at a greater distance from each other, among the Finches, where their number is still less (3 to 4). The upper windings are, in most cases, the most considerable, and likewise the most constant, whilst the lower become continually slighter, extending themselves sometimes (especially in Turdus, and likewise occasionally in Fringilla) throughout the greatest part of the tail extremity of the spermatozoon. The length and thickness of the tail, like the number and arrangement of the windings, is subject to many changes and fluctuations among the several genera. It is particularly strong and rigid among the Fringillidæ, the spermatozoa of which (as in Fringilla cœlebs, *the Chaffinch*) attain sometimes a length of $\frac{1}{6}'''$, whilst in other cases they are much shorter (in Fr. Spinus = $\frac{1}{10}'''$, F. Canaria $\frac{1}{12}'''$, F. domestica $\frac{1}{20}'''$). The tail part of the spermatozoa of the Lanidæ is, on the other hand, very short and fine, its length scarcely measures $\frac{1}{60}'''$—$\frac{1}{50}'''$, of which about $\frac{1}{200}'''$—$\frac{1}{100}'''$ goes to the anterior spiral body. The spermatozoa of Oriolus are only slightly larger. Among the Thrushes the length is about $\frac{1}{25}'''$, of which the anterior spiral body occupies quite one third. The same is the case among most other singing birds, as Sturnus, Hirundo, Parus, Alauda, Arthus, Certhia, &c. Motacilla and Emberza have spermatozoa of $\frac{1}{20}'''$, Sylvia (Phœnicurus vibilatrix) and Saxicola of $\frac{1}{15}'''$. Among the last-mentioned genera, the spermatozoa form by their shape a kind of approach to the corresponding formations of the Fringilla, whilst the spermatozoa of others remind us more of these formations in the thrushes and the Lanidæ. In other words, the formations just alluded to form a medium between the latter mentioned birds and the Fringilla.

The spermatozoa with a simple cylindrical body are much more uniform in size and shape, and differ from each other chiefly as regards the length of the tail, very little as to the length of the body.

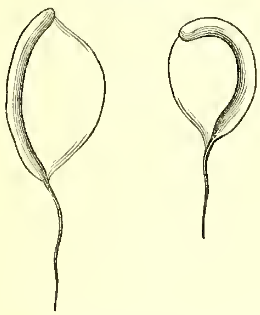
The body generally measures from $\frac{1}{150}'''$—$\frac{1}{225}'''$ (Picus, Falco, Columba, Gallus, Pavo, Anas, &c.), but seldom less (in Vanellus and Cuculus = $\frac{1}{200}'''$). The tail is very thin, and can usually only be traced to its termination with difficulty. The anterior part, which is connected with the body, is but little distinguished from the posterior, and is always without any remarkable thickening. Its length is always more considerable than the length of the body, the entire fibre generally measuring $\frac{1}{60}'''$, and rarely less (Vanellus, Cuculus) or more (Gallus, Columba).

It is an interesting fact that the difference of form of the spermatozoa in birds is associated with a difference in the manner in which they adhere to each other. Those which have a simple cylindrical body, are constantly dispersed about in the canals of the testicles without any order, whilst the spermatozoa of the singing birds are generally met with in regular bundles. The spermatozoa in each of these bundles, as in the mammalia, lie together in parallel lines, and with their tails all in the same direction. It is only in their passage through the vas deferens that the bundles gradually lose their regular connexion.

The *genesis* of the spermatozoa of birds, is essentially the same as among the mammalia. Their proportions are, however, much more distinct, and therefore more easy to trace. The examination of the domestic fowl is much to be recommended in this respect; some time ago we described

the developement of the spermatozoa of this bird.* The vesicles of developement, in this instance, have a size of $\frac{1}{200}'''-\frac{1}{150}'''$. They are as clear as glass when in a fresh state, and the spermatozoon in the interior can very readily be observed. At the commencement they are globular. Subsequently the shape becomes more irregular; sometimes it assumes that of a pear, until finally the enclosure bursts (which generally takes place at the sharp extremity), when the spermatozoon makes its exit with the tail end first (*fig.* 330.).

Fig. 330.

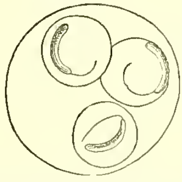


Spermatozoa of the Cock partly enclosed by the Cell of Developement.

For some time afterwards, the remainder of the vesicle of developement may be seen adhering to the separate spermatozoa.

All the cells of developement, however, are not free. We often find large cystiform globules, enclosing a number of three, four, eight, twelve, or sixteen cells of developement, much more frequently than among the mammalia; these generally have a diameter of $\frac{1}{100}'''-\frac{1}{80}'''-\frac{1}{50}'''$. But the persistency of these mother cells does not hinder the developement of the spermatozoa in any way. The enclosed cells of developement are equally as capable of producing these formations as the free ones, as one may readily convince oneself by observation through the microscope (*fig.* 331.). On the destruction

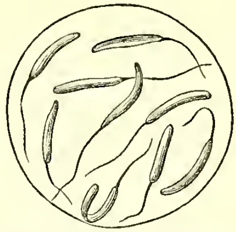
Fig. 331.



A Mother Cell from the Cock, with three Spermatozoa still enclosed in their Cells of Developement.

of the membrane of the cells of developement, the spermatozoa get into the interior of the cysts (*fig.* 332.), where they lie together often in a great number, but never in regular fascicular groups. Finally, this cyst also gets dissolved, without, however,

Fig. 332.

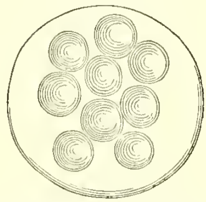


A Mother Cell from the Cock, with Spermatozoa free in its interior.

having changed its shape in any remarkable way previously. The spermatozoa common to each cyst, however, remain together for a time, being connected by means of the tough albuminous contents of the mother cell. Thus, at least, we feel inclined to explain the occurrence of irregular groups of spermatozoa, which, kept together by one common cement, not unfrequently occur in the semen of the cock.

According to our observation, the developement of the spermatozoa of the woodpecker and of the pigeon takes place in precisely the same manner; and this may be said likewise of singing birds.* The cells of developement of the latter are however still more rarely to be met with free, and are perhaps always enclosed by mother cells. The number of the enclosed cells is generally very considerable (*fig.* 333.).

Fig. 333.



Cyst of the House Sparrow, with enclosed Cells of of Developement.

The formation of the spermatozoa in the interior of the individual vesicles of developement is likewise very difficult to be traced, principally because the contents of the latter coagulate very readily, thus covering the spermatozoa, and rendering them indistinct. We have, however, succeeded several times in observing the spermatozoa in the house sparrow in the interior of their cells of formation (*fig.* 334.). It certainly requires some practice to discover the windings of the body between the granules of the contents, the

* Lehrbuch der Physiol. 3d edit. § 18. S. 27.

* Vide R. Wagner's figures in Müller's Archiv. 1836, S. 225., in Fragm. zur Physiol. der Zeugung; in Lehrbuch der Physiolog. § 17. S. 25.; as also in the Icon. Phys. tab. I. *fig.* 5. (copied in the article, Entozoa, Vol. II. p. 112.), which however, in consequence of our recent researches, require some correction.

more so as the characteristic spiral twistings have not yet assumed that distinctness and

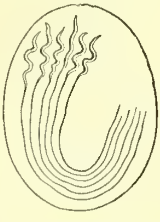
Fig. 334.

Cells of Developement with Spermatozoa of the House Sparrow.

regularity, which they subsequently attain. The presence of the spermatozoa can only be proved with certainty, when they have become free, after the dissolution of their formative cells, the mother cyst still continuing to encircle them. Thus we may also explain the former conjecture of one of us, R. Wagner, who thought that the spermatozoa of the singing birds had their origin immediately in the interior of the large cysts.

The spermatozoa of the singing birds do not however lie together irregularly in the interior of these cysts, as in the cock, the pigeon, &c., but are associated in very definite fascicles, as already described. We are ignorant as to the cause of this arrangement. The number and grouping of the cells of developement in the interior of the cysts do not present any remarkable differences from those in the cock, &c., although the spermatozoa of the latter are constantly devoid of such a regular arrangement. The spermatozoa of the singing birds likewise remain enclosed for some time by the membrane of the mother cysts. At the commencement they lie with reverted tails close to the interior wall of the cysts, which then assumes an oval form (*fig.* 335.). Subsequently the tail ends of

Fig. 335.

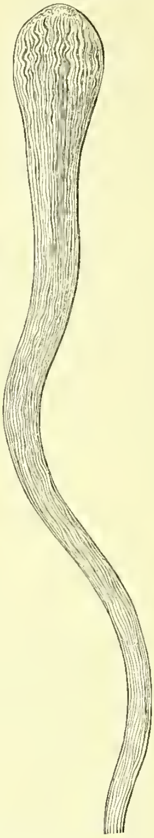


Mother Cell with a Bundle of Spermatozoa from Fringilla domestica.

the spermatozoa remove themselves further and further from the anterior bodies. The cyst bursts where the points of the tails are situated, and the bundles, which are still covered at the anterior end by the remains of the cyst, as if by a cap, then assume the shape of a retort, or of a knee-shaped bent cylinder. Even in cases in which the spermatozoa have perfectly separated themselves (*fig.* 336.), this remainder of the former cyst can generally be traced. We may also see very distinctly a tough albuminous substance between the individual spermatozoa, from which the tail ends project freely.

These proportions experience a small modification in those singing birds, in which the

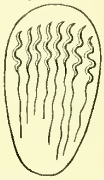
Fig. 336.



A Bundle of Spermatozoa from Fringilla cœlebs.

tails of the spermatozoa are shorter than among the Lanidæ. The cysts here retain almost entirely their original form, or do not enlarge to any extent (*fig.* 337.). The

Fig. 337.



Bundle of Spermatozoa in the interior of a Cyst of Lanius.

spermatozoa in this case lie quite straight in the cyst from the commencement, and subsequently pierce the posterior end of it with their tails.

Reptilia. — The spermatozoa of the reptilia possess the same shape as those of birds; that is to say, an oblong cylindrical body, and a very fine hair-like tail.

No great differences present themselves in the form of these elements among the rep-

tilia with scales. Lizards, snakes, and tortoises uniformly possess, like most birds, a simple and straight body (*fig.* 338.), which, however, is occasionally rather pointed towards the anterior part. This occurs, for instance, in the snakes. The only difference consists in the difference of breadth of body and tail. In the snakes (Coluber), in which the

Fig. 338.

Spermatozoa of Lacerta agilis.

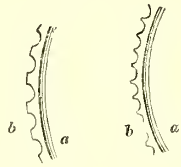
Fig. 339.

Spermatozoon of Rana temporaria.

spermatozoa measure about $\frac{1}{25}'''$, the length of the body amounts to only $\frac{1}{300}'''$; in the lizards (Lacerta), on the other hand, in which the spermatozoa are smaller ($\frac{1}{60}'''$—$\frac{1}{50}'''$) about $\frac{1}{200}'''$.

The differences of the form of the spermatozoa are however much greater in the group of the *Batrachia*, which likewise distinguish themselves in other respects by various deviating circumstances. A staff-like body with a very thin and proportionately short tail characterise the spermatozoa of Rana and Bufo (*fig.* 339.). The length of the spermatozoa here amounts to about $\frac{1}{50}'''$—$\frac{1}{40}'''$, of which the body occupies more than the anterior third. Among the Salamanders the body is likewise cylindrical, but much longer ($\frac{1}{30}'''$), bent in the shape of a sabre, and thickest at its posterior end.* Towards the anterior part it becomes gradually thinner, and (in Salamandra at least) furnished at the point with a very small globular knob. The tail is likewise of a considerable length. In the anterior part, which passes into the body, it possesses a not inconsiderable thickness. Towards the posterior part it becomes finer and thinner, until at last it can only be traced with difficulty. The end of the tail is, however, not straight, nor curved like the anterior part, but turned up in a remarkable manner, and wound in very numerous narrow spirals round the commencing part of the tail, and even round the body. At least so we may explain the peculiar structure of the spermatozoa of Salamandra, and in this we agree with V. Siebold.† Others, especially French naturalists, as, for instance, Pouchet, merely suppose the slender fibre, which is so twisted round, to be the contour of a ridge-like formation, which is assumed to be seated on the body lengthwise, and which is said to be bent in a zig-zig manner to the right and left. It is true that this fibre is frequently only seen to rise on one side of the spermatozoon, and in a shape which would encourage the conjecture just now alluded to (*fig.* 340.);

Fig. 340.



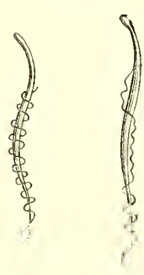
Part of Spermatozoon of Triton.

a, body of the spermatozoon; *b*, spiral windings of the delicate tail.

but in other cases the twistings are so distinct that they are not to be denied. We are of opinion that, whenever the tail has been lying only on one side of the spermatozoon, a partial twisting off has taken place. This notched appearance may be attributed to the tail fibre retaining its spiral twistings. It is, however, remarkable that the tail never moves further from the trunk of the body, constantly maintaining only a certain distance from it. We do not venture to decide the cause of this, yet we cannot see in it a positive proof of the correctness of *Pouchet's* view.

The length of the spermatozoa is very considerable. From the anterior point of the body down to the region where the tail bends itself, they measure in the Salamander $\frac{1}{10}'''$, in Triton even $\frac{1}{5}'''$. The spermatozoa of the Proteus seem to possess a still greater length, according to an imperfect statement of *Valentin.**

Fig. 341.



Spermatozoa of Bombinator igneus.

The spermatozoa in Bombinator igneus (*fig.* 341.) are of a structure quite similar to those of the Salamander, only smaller. The body of the former is staff-shaped, tolerably long, and getting thinner towards both ends. The point is again rather enlarged, and flat-

* Vide copies in R. Wagner; Fragment. Tab. II.

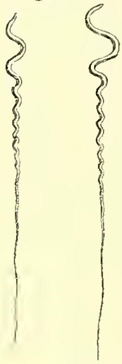
† Froriep's Neuen Notizen, vol. ii. S. 281. No. xl.

* Repertorium fur Anat. &c. 1841, S. 356.

tened. The posterior end is continued into the tail, which latter is tolerably thick, and almost straight at its commencement. It gradually, however, assumes a very thin appearance, becoming a very attenuated hair-like appendix, which exhibits the same spiral windings that occur among the Salamanders. The length of the spermatozoa, as far down as where the tail bends itself, amounts to $\frac{1}{60}'''$—$\frac{1}{50}'''$.

Another very singular form of spermatozoa is met with in Pelobates fuscus. The spermatozoa measure $\frac{1}{25}'''$. There is no boundary perceptible between the body and tail part, but one half of the spermatozoon distinguishes itself from the other by a considerable thickness. Both, however, gradually pass into one another. The thicker part exhibits from its commencement a number (generally eight) of spiral windings, which increase in size towards the anterior free end (*fig.* 342.). The anterior

Fig. 342.



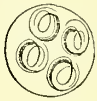
Spermatozoa of Pelobates fuscus.

end itself does not however participate in this formation. It is of a more delicate quality, paler, and has a constant vibrating motion, which gives to it a varying form. It generally appears to be wound in an undulating manner.

A fascicular group of the spermatozoa is only found among the Reptilia in Batrachians; Bombinator, however, forming an exception. In the latter, as well as in the scaly Reptilia, the spermatozoa lie confusedly together. In the latter instances we can readily trace their production in the interior of separate solitary cells of developement; as, for instance, in Anguis fragilis, or Bombinator igneus. The cells of developement of the latter animal (which to the number of two or four are enclosed by a mother cell, when in the earlier stages of developement) measure in a developed state about $\frac{1}{100}'''$. At first, when the spermatozoon forms itself in the interior of these cells, it lies curled up close to the wall. Subsequently the fibre stretches itself, and changes the cell into an obtuse cylindrical enclosure, which finally bursts in the anterior and posterior part, to enable the spermatozoon to make its exit. The remains of the cell of developement continue for a long time adhering to the body of the spermatozoa, generally in the centre, exhibiting the appearance of a comb-like appendix of a variable shape and size.

The formation of the spermatozoa in the interior of independent cells of developement likewise takes place in a similar manner in the Lacerta crocea. We have but rarely seen that the same cells are enveloped by larger cysts at the period of the production of the spermatozoa, which is commonly the case in former stages of the developement. The number of cells contained in one common cyst is generally only very small, seldom exceeding eight. The same is found, according to the

Fig. 343.



Cells of developement of Testudo græca with Spermatozoa and external cysts. (After Kölliker.)

observations of Kölliker, in Testudo græca; but the external cyst in this instance is said generally to persist for a longer period. The persistency of this enclosure is very general among the Batrachians, which distinguish themselves by the spermatozoa being associated in fasciculate groups. The number of the enclosed cells of developement here is generally a larger one (from ten to twenty). The developement of the spermatozoa in other respects does not, however, exhibit anything peculiar. They are formed as usual, separately in the enclosed cells of developement (*fig.* 344.). It is only afterwards,

Fig. 344.

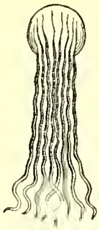
Developing cell of the Frog, with a Spermatozoon in its interior. (After Kölliker.)

when these cells have been dissolved, that the spermatozoa get into the interior of the mother cyst, in which they congregate in fasciculate groups. By their so doing the cyst loses its original round shape, and assumes the form of a pear, until it bursts at the pointed extremity, and the tail-ends of the spermatozoa immediately project. The remains of the cyst continue recognisable for some time at the anterior end of each bundle. This is the case in the frog at any rate. In Pelobates, on the other hand, the filiform tails of the spermatozoa do not project from that part of the cylindrical enclosure which is burst, but the anterior vibrating body does so (*fig.* 345.).

The external cyst of the bundles of spermatozoa of the Salamander constantly retain its original globular shape, as the sperma-

tozoa do not stretch but remain wrapped up. It is a remarkable sight to see the cyst burst-

Fig. 345.

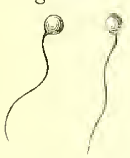


A bundle of Spermatozoa of Pelobates.

ing on being treated with water. The whole mass of spermatozoa suddenly bursts forth, and only remain attached to each other by the heads, as if imbedded in one common substance. The separate fibres radiate in all directions, each being wrapped up in a spiral form.

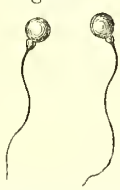
Fishes. — In the class of fishes, the spermatozoa occur in two forms. The first is found throughout the osseous fishes, and also in Amphioxus. The other form is found among the Plagiostomes. In the former case the spermatozoa consist (*fig.* 346.) of a very small globular body (of $\frac{1}{500}'''$—$\frac{1}{800}'''$, or even smaller, down to $\frac{1}{1000}'''$, as in Perca fluviatilis), and an extraordinarily thin, hair-

Fig. 346.



Spermatozoa of Perca fluviatilis.

Fig. 347.



Spermatozoa of Cobitis fossilis.

like tail, which, however, possesses comparatively a very considerable length. Sometimes the body at the point of insertion of the tail has a small knotty appendix, as in Cobitis (*fig.* 347.), which gives to it a pear-like shape. The body in some genera is so small that it can hardly be perceived with any distinctness.

This also applies to the spermatozoa of Petromyzon, in which the form of the body is, however, different. In P. marinus* the body is egg-shaped; in P. fluviatilis (*fig.* 348.) staff-shaped. The length of the body in P. fluviatilis is $\frac{1}{150}'''$.

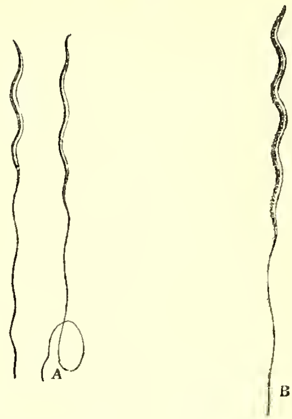
Fig. 348.

Spermatozoon of Petromyzon fluviatilis.

The spermatozoa among the Plagiostome fishes are similarly formed to those of the birds. They are long, filiform, and furnished with an anterior cylindrical body. In Scyllium Canicula the body is stiff and quite straight, and tapers at both ends. The tail is thin, and of an equal length to the body ($\frac{1}{40}'''$).

The spermatozoa of Scymnus niceænsis (*fig.* 349. A) are similar but rather longer, whilst

Fig. 349.

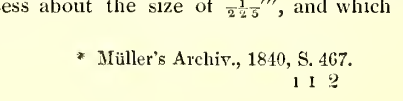


A. *Spermatozoa of Scymnus niceænsis.* B. *Spermatozoon of Torpedo Narce.*

the body, instead of being straight, describes two long spiral windings. Four more narrow spiral windings are found round the body of the spermatozoa in Spinera acanthias, which measures $\frac{1}{30}'''$, whilst the length of the whole spermatozoon amounts to $\frac{1}{12}'''$ A similar number of spiral twistings are likewise seen in the body of the spermatozoa of most of the rays, in Torpedo narce (*fig.* 349. B), Raja rubus, &c. In Raja oxyrhynchus it is only the anterior part of the body which is spirally wound in a length of about $\frac{1}{60}'''$, whilst the posterior part is straight. The number of the windings is nevertheless, however, more considerable, viz. 7 or 8. The length of the whole spermatozoon amounts to $\frac{1}{15}'''$. Chimera monstrosa likewise exhibits these windings, notwithstanding the comparatively short body ($\frac{1}{100}'''$) of its spermatozoa, which have a length of $\frac{1}{25}'''$. The number of windings is three.

The developement of the spermatozoa in fishes has as yet only been observed in the Plagiostomes. It is exactly the same as in frogs and birds, as the statements of *Hallmann** lead us to infer. Almost all of the spermatozoa are united with one another in bundles. According to our researches in Torpedo Narce, the spermatozoa are produced sepa-

Fig. 350.



Cysts, with developing cells from the testicle of Torpedo Narce.

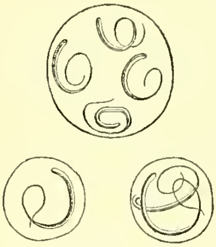
rately in the cells of developement, which possess about the size of $\frac{1}{225}'''$, and which are

* J. Muller, Untersuch. uber zu Eingewerde der Fische, Berl. 1845, S. 6.

* Müller's Archiv., 1840, S. 467.

enclosed by a lesser or greater number of cyst-like mother cells (*fig.* 350.). The size of each of these cysts amounts to about $\frac{1}{100}'''$, wherever the number of the enclosed cells is small; but in the reverse case it may increase to $\frac{1}{30}'''$. The cells of developement dissolve after the formation of the spermatozoa, and the latter then get into the interior of the cyst (*fig.* 351.). The spiral wind-

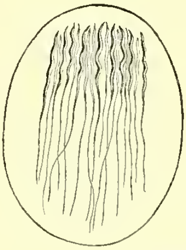
Fig. 351.



Spermatozoa in the interior of the cysts (Torpedo Narce).

ings of the body seem to be still wanting at this stage, or, at least, not to be perfectly developed. If the number of spermatozoa is only small in one cyst, they never group together into a bundle, whilst this is constantly occurring in the reverse case (*fig.* 352.).

Fig. 352.

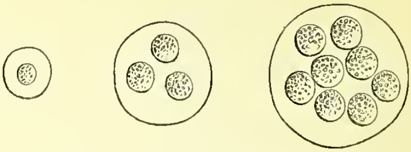


Bundle of Spermatozoa in a cyst (Torpedo Narce).

We will not venture to decide, however, whether this difference is entirely attributable to the greater number of the cells of developement; and we are the less inclined to do so, as we have already seen, when investigating the spermatozoa of birds, that, even with an equal number of the formations alluded to, the grouping of the spermatozoa in the interior of the cyst may be different. This much, however, is certain, that the number of the enclosed cells is not entirely without influence. The fact of the fascicles of spermatozoa always coinciding in one cyst with a greater number of the cells of developement, seems, at all events, to favour this conjecture.

Previous to the period of procreation, we also find, in the testicles of the *osseous* fishes, that the cells of developement are enclosed in the interior of larger cells (*fig.* 353.); but here, as well as in the Lacerta, &c., the formation of the spermatozoa only takes place

Fig. 353.



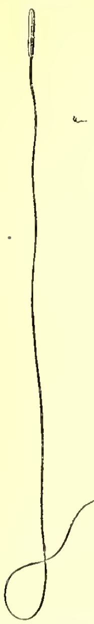
Spermatic cells from Cyprinus brama.

subsequently to the destruction of the cyst, and to the consequent independence of the cells of developement. We infer this from the circumstance that we have never seen in them any real bundles of spermatozoa. The statement of *Kölliker* that the spermatozoa of Amphioxus develope themselves from little cells (of $\frac{1}{1000}''' - \frac{1}{750}'''$), which lie together in groups of from six to twenty-five, also seems to support the correctness of our conjecture. Each of such groups appears to us to be the brood of a single mother cell. The mother cells themselves, however, are of such a small size, that the formation of such brood in their interior is not to be traced or perceived. It can only be seen that these cells gradually lose their round shape, and that they assume a pear, or spindle-like form. This, unquestionably, is merely the consequence of the endogenous developement of a spermatozoon, which gradually stretches itself, thereby causing (as in Gallus, Rana, &c.) the change of shape of the external enclosure.

Thus much of the proportions of form, and of the mode of developement of the spermatozoa among the Vertebrata. We have treated this subject somewhat elaborately, partly because the spermatozoa of these animals are those which may be most frequently obtained for observation,—partly also because it is in them that the stages of developement can be better traced and recognised. We have invariably met with in them a common type, not merely in the external shape, but also in the mode of developement of the spermatozoa; and these are circumstances which will be of importance to us in interpreting the stages of developement of the spermatozoa in the lower animals, in which they are as yet enveloped in great obscurity.

Mollusca.—Among the Invertebrata, the division of the Mollusca uniformly possesses (as in the Vertebrata) filiform spermatozoa, which are enlarged at the anterior extremity. This anterior extremity does not, however, every where form a particular division, as a body, distinct from the posterior thinner part or tail. On the contrary, the one passes in many cases so gradually into the other, that it is impossible to determine the boundary between the two. The tail then appears to be a mere pointed continuation of the anterior enlarged part. The two thus distinct forms of spermatozoa are, however, again united with one another in various ways.

Fig. 354.



Spermatozoon of Octopus vulgaris.

Cephalopoda.—In the Cephalopods we meet with the former form of spermatozoa with a distinct body and a thin and long hair-like tail, as among the scaly reptilia, &c. The body is cylindrical, or staff-shaped, in the spermatozoa of Octopus vulgaris (*fig.* 354.), which have a length of $\frac{1}{8}'''$, of which $\frac{1}{125}'''$ belongs to the anterior body.

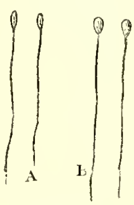
The spermatozoa in Sepiola are shorter, and furnished with a body which measures $\frac{1}{250}'''$.

The developement of these spermatozoa occurs just as in birds, according to *Kölliker*. The separate spermatozoa may be perceived very distinctly in the interior of their cells of developement. The fascicular grouping is wanting, although the spermatozoa remain enclosed for some time by the mother cells.

These fibres in the Cephalopods are, however, surrounded in their passage through the vas deferens by peculiar sack-like enclosures or *Spermatophores*, which are formed from the secretions of the gland contained within the walls of that channel. These enclosures gradually assume a very strange complicated structure, which we have only become acquainted with, within a recent period, through the excellent researches of *Milne Edwards.** They assume the shape of cylindrical bags of a not inconsiderable size, so that they may readily be perceived with the naked eye. They contain at the posterior extremity a peculiar apparatus (besides the Spermatozoa, which are accumulated at the anterior thicker end), which is distinguished by a particular mechanism adapted for the expulsion of the seminal liquor.

Gasteropoda.—The spermatozoa of the Gasteropods exhibit, only in rare cases, as it seems,

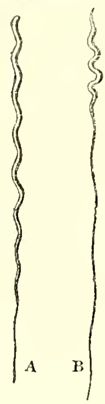
Fig. 355.



Spermatozoa : A, *of Patella ;* B, *of Chiton.*

a similar form to those of the Cephalopods. This is the case, for instance, in Chiton and Patella (*fig.* 355.). The spermatozoa of the former consist of thin delicate fibres of $\frac{1}{50}'''$, the anterior body of which has an oblong shape, measuring about $\frac{1}{800}'''$. The body in Chiton is broader, almost pear-shaped, and of a more considerable size ($\frac{1}{500}'''$). Similar cercaria-like spermatozoa are possessed by Halyotis and Bermetus, as also by Trochus and Paludina impura. The strict distinction between body and tail is, however, wanting in most of the other Gasteropods. The spermatozoa then have a filiform shape, and increase gradually in thickness from the posterior, pointed, towards the anterior end. The head or cephalic end is flattened. It is thus, for instance, in Carinaria ; also among the Nudibranchiata, Hypobranchiata, Pomatobranchiata, and *Pteropods.* At the same time the spermatozoon usually exhibits a number of light spiral windings, which diminish uniformly from the anterior to the posterior end (*fig.* 356. A). In Paludina vivipara (which,

Fig. 356.



Spermatozoa, A, *of Doris ;* B, *of Paludina vivipara.*

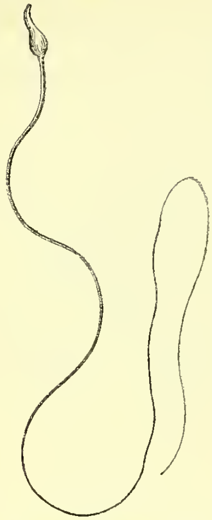
from the form of the spermatozoa, likewise belongs to this description, although the thinner tail part is distinguished by a greater length) the spiral windings are closer, as among the singing birds, and confined to the anterior body only (*fig.* 356. B). The spermatozoa of most of the other species of this genus possess quite a different form. In Turbo, Buccinum, Purpura, they are simply filiform, and equally pointed towards both ends. In Turbo they measure $\frac{1}{50}'''$—$\frac{1}{40}'''$, in Thedys, Aplysia $\frac{1}{10}'''$, in Pleurobranchia Meckelii even $\frac{1}{6}'''$, &c.

The spermatozoa of *pulmonary Gasteropods* are usually still larger, extending to 1''', as in Helix. As in the Nudibranchiata, they likewise become gradually enlarged towards the anterior part, but not flattened at the cephalic end, being, on the contrary, furnished with a short point (in Helix of $\frac{1}{250}'''$), with an appendix, which must be viewed as a peculiar form of body (*fig.* 357.). The same is thickest at the posterior part, thicker than the body, and gradually gets thinner towards the end. In most cases (Helix, Arion,

* Annales des Sciences Nat. 1842, tome xvii. p. 335.

Clausilia, &c.), it exhibits two easy spiral windings, almost in the form of an S. Some

Fig. 357.



Spermatozoon of Helix pomatia.

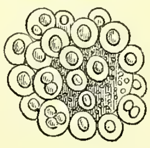
easy spiral windings are also not unfrequently observed at the enlarged body.

The *mode of formation* of these spermatozoa can usually be traced without any great difficulty. It usually takes place in the same way as in the animals already described, as proved by *Kölliker's* excellent researches. Even in the Gasteropods we may observe the developement of the spermatozoa in the interior of particular vesicles. The arrangement of these parts only exhibits some deviation.

In Helix or Clausilia, in which the stages of this mode of developement can best be observed among our native snails, we meet with in the interior of the testicle, besides the developed spermatozoa, numerous larger and smaller aggregations of vesicles (in number varying from ten to forty), which are seated on the external surface of a round or oval globule (*fig.* 358.), which is in diameter $\frac{1}{100}'''$ to $\frac{1}{50}'''$.

On a nearer research, it will be found that this globule is not a cell, as one might suppose at first sight, but merely a mass of a

Fig. 358.

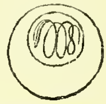


Group of vesicles from the testicle of Helix pomatia.

tough substance, in which a number of small brown granules are embedded, exhibiting a great similarity with the yolk molecules from the eggs of Helix. There is no external enclosure around this globule. The peripheral vesicles or cells, which adhere to it frequently in an irregular manner, generally measure $\frac{1}{150}'''$, but are sometimes larger, to the extent of $\frac{1}{100}'''$ and above it. In the interior of these cells we meet again with vesicular formations, generally measuring $\frac{1}{200}'''$. The contents of these vesicles coagulate on being treated with water, &c., into a fine granular mass, exhibiting sometimes a simple or double granule of extraordinary size. The number of the enclosed vesicles, which evidently were produced in an endogenous way, is usually very small, mostly 1 or 2, more rarely 3, 4, or 6.

The developement of the spermatozoa takes place in the interior of these last-mentioned vesicles (*fig.* 359.). According to the

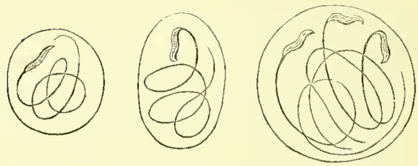
Fig. 359.



Spermatozoon of Helix pomatia in the interior of its developing cell. (After Kölliker.)

observations of *Kölliker*, the head is produced first, being at first of a less regular, unwieldy shape. The tail is formed subsequently, attaching itself in spiral windings to the internal surface of the cell wall. On the spermatozoa being sufficiently developed, the vesicle of developement is dissolved, and the spermatozoa get into the cavity of the external cell (*fig.* 360.). Here they may usually

Fig. 360.



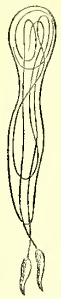
Spermatozoa of Helix pomatia in the interior of their mother cells.

be perceived with great distinctness, whilst they can but rarely be distinguished in the interior of the real cells of developement.

At first the mother cells retain their original round form, even after the reception of the spermatozoa. They soon, however, on the windings of the fibres being stretched, extend themselves lengthwise, and assume an elliptical or pyriform shape. At a still later period the cell pushes forward (at the point where the heads of the spermatozoa are situated) a long pedicle-formed process, which contains the anterior extremity of the spermatozoa (*fig.* 361.). The point of this process or continuation constantly remains connected with the central globule of the former mass of vesicles, whilst the posterior belly-like part of the cell removes itself further and further from it. The same attachment takes place afterwards with the heads of the spermatozoa, on their being projected from the anterior end of this process, which usually happens soon. At this period the mass of vesicles reminds us

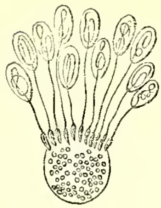
strongly, owing to its shape, of a group of vorticellæ (*fig.* 362.).

Fig. 361.



Spermatozoa of *Helix pomatia* at their extrusion from the mother cell.

Fig. 362.



A group of Spermatozoa of *Helix pomatia*, partially protruded from the mother cell.

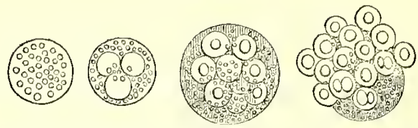
As soon as the heads of the spermatozoa have projected, the remainder of the mother cell lengthens itself, and becomes a delicate cylindrical envelope. These remains still adhere to the spermatozoa when completely extended, exhibiting the appearance of a couple of larger or smaller knobs on the tail: the same thing occurs in the spermatozoa of the frog.

This mode of developement is not changed by the presence of a greater number of spermatozoa in the interior of the mother cell. All the difference that may be seen is, that one spermatozoon comes forth rather earlier than another. The free spermatozoa are, however, by no means distributed without order over the surface of the central globule to which they still adhere. On the contrary, they are grouped together into one common fasciculate mass, in the same manner as we have already described in the singing birds. This circumstance is remarkable, because it shows us that the formation of a bundle of spermatozoa is not occasioned everywhere by the same means, and therefore does not always justify the inference of the persistence of an enclosing cell.

A separation of the bundles of spermatozoa happens in Helix: the central globule (which forms the common cement that holds together the individual spermatozoa, in the same way as the tough albuminous mass in the cysts of the singing birds) gradually passes away.

The developement of the group of vesicles in Helix is very interesting and important. It is at once apparent that the same has originated from the brood of a single, originally simple, cell, and that through a continual endogenous increase. Our researches have afforded us the immediate proof of the truth of this, confirming, at the same time, the conjecture of *Kölliker;* viz. that the primitive spermatic cells are the same formations which have been described as epithelial cells of the follicles of the testicle. In the interior of these cells, the contents of which consist of a brownish granular homogeneous substance, a certain number of vesicles are gradually produced, which continually increase in an endogenous manner, until the bursting of the mother cell, when the daughter cells deposit themselves around the globular remainder of the cellular contents (*fig.* 363.).

Fig. 363.



Formation of groups of vesicles around the epithelial cells of the testicle in Helix pomatia.

The developement of the spermatozoa in the other Gasteropods is similar to that described, although not in all cases so distinct as in Helix. The endogenous formation of the spermatozoa can only with difficulty be perceived in Lyma, Lymnæus, &c.; it would rather appear as if they were produced by immediate growth from vesicular elements. The general rule is, that they are united with each other into groups, in which, however, the interior central globule is sometimes wanting (as in Cyclobranchiata, in Turbo, Buccinum, &c.); but this does not change in any way the developement and mode of grouping together of the spermatozoa. We have also, in this instance, in the united vesicles of a group, unquestionably only the brood of a common mother cell, which group may have enlarged after the destruction of the external membrane that surrounded it. The only difference would consist, in the circumstance that the entire contents of the mother cell are employed for the structure of the daughter cells, leaving no remainder, which perhaps might induce a more firm connection of the separate vesicles in the shape of a round mass.

Acephala. — In comparison with the variety in the form of the spermatozoa among the Gasteropods, we meet with but slight differences in the class of the Acephala, at least among the Lamellibranchiates.* The spermatozoa of these Mollusca consist of delicate fibres of about $\frac{1}{50}'''$ in length, the anterior end of which supports a short and distinct body of variable size (from $\frac{1}{1000}'''$ — $\frac{1}{400}'''$) (*fig.* 364.). This body is usually (as in Unio, Cyclas, Clavagella) cylindrical; in other cases (for instance in Mytilus, Pholas) pear-shaped.

Fig. 364.

Spermatozoon of Unio.

Respecting the formation of these fibres we only know *Kölliker's* opinion of it, viz. that they are produced in bundles from round cellular masses, and through an apparent prolongation of the vesicles; as, for instance, in Chiton, &c.: our examination of Unio was not calculated to give us an insight into it.

* Vide V. Siebold in Müller's Archiv. 1837, S. 381.

I I 4

Tunicata.—Among the Tunicata the Ascidia possess spermatozoa quite similar to those of the Lamellibranchiates, having a distinct head of different shape and a slender tail. The size of the spermatozoa is, however, usually rather larger (*fig.* 365.); the head is usually $\frac{1}{100}'''$—$\frac{1}{80}'''$, the tail fluctuating between $\frac{1}{60}'''$—$\frac{1}{25}'''$. The spermatozoa seem to want a body in the Salpæ, according to the observations of Kölliker.

Fig. 365.

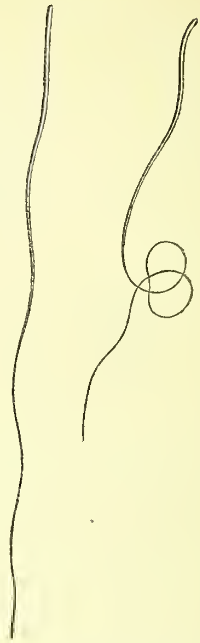
Spermatozoon of Phalluria monacha. (After Kölliker.)

The endogenous formation of the spermatozoa in the Ascidia is as little distinct as among the Lamellibranchiata. It seems, also, with regard to the former, that the developing vesicles simply extend themselves into the spermatozoa. At a previous stage of developement, these vesicles are, however, contained (either singly or in a greater number) in the interior of cells.

Articulata.—In the second great division of the Invertebrate animals, among the *Arthropoda*, the filiform shape of the spermatozoa, if indeed it occurs at all, is generally still more marked in its developement than in the Mollusca. The spermatozoa are long and slender fibres, which, perhaps in all cases, are deficient of a real, distinct, and separate body, being at the utmost only slightly enlarged at the anterior end. The spermatozoa of some few groups, however, differ from this, and exhibit so striking a form and arrangement that one can hardly at first recognise in them the genuine spermatic elements. The question, indeed, arises, whether these parts are really in all cases the developed spermatozoa, or whether they do not constitute mere stages of developement. We shall subsequently return to this question; let the remark suffice for the present, that in some cases the circumstances observed seem to favour the latter hypothesis.

Insecta.—The spermatozoa among the *hexapod insects* are of great uniformity. They appear, without exception, as filiform fibres (*fig.* 366.), which are frequently distinguished by being extremely slender in proportion to their length (the latter exceeds 1''' in Staphylinus, but is generally less; in Culex $\frac{1}{25}'''$; in Agrion Virgo $\frac{1}{60}'''$—$\frac{1}{50}'''$). The anterior end is probably always rather thickened for a considerable extent, and thereby distinguished from the posterior pointed end of the fibre. Remarkable deviations from this fundamental shape occur but rarely, but are nevertheless not entirely wanting. We may mention, for instance, that a peculiar angular appendix is found in the spermatozoa of the Locustinæ at the anterior end of the body, this appendix being formed of two short crura, which converge and pass into one towards the anterior part, like the head of an arrow.

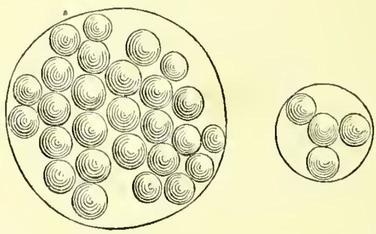
Fig. 366.



Spermatozoa of an Insect.

The spermatozoa of the Hexapods are developed in the same endogenous manner, as among the Vertebrata. This process may very easily be observed. The vesicles of developement, which measure pretty uniformly, when in a developed state, $\frac{1}{200}'''$ (they are smaller in many Diptera, Culex ($\frac{1}{300}'''$), Musca,

Fig. 367.



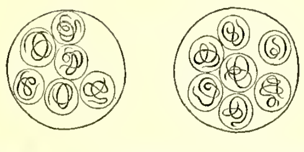
Cysts, with developing vesicles, from the testicle of Staphylinus cyaneus.

&c.), are in a variable, generally, however, in considerable number (twenty, thirty, forty), enveloped by larger cysts (*fig.* 367.) These cysts or enveloping cells frequently attain the size of $\frac{1}{25}'''$ (Carabus, Staphylinus, Locusta, &c.), and they are evidently the mother cells of the enclosed vesicles. In the upper division of the testicle, the

number and size of the latter is generally much smaller than in the lower part. It follows, of course, that the size of the mother cells themselves is influenced by the size and number of their contents: wherever the number of the enclosed vesicles is small, the cyst never attains a considerable size. In Culex, for instance, it seldom exceeds $\frac{1}{100}'''$ — $\frac{1}{75}'''$.

The vesicles surrounded by the cyst are as clear as glass, and, when uninjured, contain an entirely homogeneous material, which, however, appears granulated on being treated with water, and then also it sometimes forms a

Fig. 368.

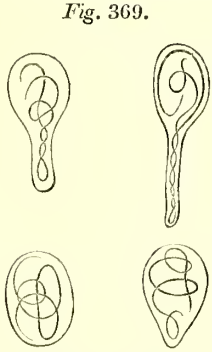


Developing cells of the Spermatozoa of Culex.

large nucleus-like body in their interior. In each of these vesicles, as *V. Siebold** has shown, a single spermatozoon is usually produced (*fig.* 368.). It attaches itself in numerous windings to the inner surface of the cell wall, until it has reached its full developement. In the mean time the vesicle loses its original round shape, becoming stretched, and assuming the most various forms (*fig.* 369.). At last the vesicle bursts at some place, and allows the spermatozoa to come forth. (*Fig.* 370.)

The spermatozoa having thus become free, group themselves together into regular bundles, still enclosed by the mother cell of the vesicle of developement. This at least seems to be the case invariably wherever the cyst persists long enough. It, however, some-

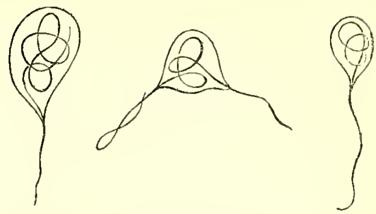
Fig. 369.



Spermatozoa in the interior of the vesicles of developement of Nepa cinerea.

times disappears at an early period, as, for instance, according to *Kölliker*, in Musca, in which case the vesicles of developement form loose groups, as in Amphioxus.

Fig. 370.

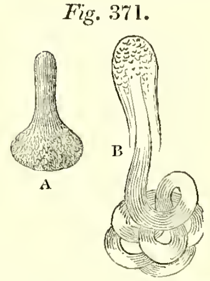


Spermatozoa partially expelled from the vesicles of developement of Nepa cinerea.

The bundles in many cases disperse as soon as the mother cells are destroyed. But it still more frequently occurs that these bundles survive the existence of the cyst, the remainder of which then covers for some time to come (as in the singing birds, &c.) the anterior end of the bundle in a cap-like form. (Instances — Coleoptera, Neuroptera, &c.) In this part, which is generally lengthened, the separate spermatozoa lie together in a remarkably dense manner, being almost united together into one common mass.

It is different, however, in most cases with the posterior division of the bundles (*fig.* 371. A.), where the separate fibres start away from each other. In this way the usual pear, club, or retort shape of the spermatozoa bundles is produced.* It is but rarely the case that the spermatozoa present, in their whole length, an arrangement similar to that which is usual at the anterior end. The whole bundle of spermatozoa then appears as (*fig.* 371. B) a homogeneous structure, and might

Fig. 371.



Bundles of Spermatozoa, A, *from the testicle of Staphylinus erythropterus;* B, *of St. cyaneus. (After Siebold.)*

readily be taken for a single colossal spermatozoon, if the observation of the developement had not taught us otherwise. Of this, however, we may convince ourselves by ma-

* Über die Spermatozoiden der Locustinen, A. *a. o.* S. 1.

* We are inclined to regard as bundles of spermatozoa of this kind, those formations from the testicle of *Paludina vivipara*, which *V. Siebold* described as a second form of spermatozoa. Müller's Archiv. 1836, S. 246.

nipulation, pressure, &c., whereby the separate constituent elements can be demonstrated. In Staphylinus cyaneus (*fig.* 371. B) these bundles are wrapped up into one roundish knot (excepting the anterior ones, which are still covered by the remains of the cysts); in Panorpa communis they have curled arrangement.

In many cases, several of such fibres join themselves lengthwise into one restiform mass, which is still covered in the interior of the testicles by a common gelatinous enclosure. This produces the long vermiform bodies, which are so frequently met with in the testicles of the butterflies, but which also occur in some few other insects, as in Diptera (*e. g.* in Scatopsis).

In their gradual advance through the vas deferens, the spermatozoa lose this mode of grouping; — their bundles separate. In the place of this they are, however, very frequently enclosed in masses by peculiar baglike enclosures, the so-called *Spermatophora* *, such as we find in the spermatozoa of the Cephalopods, only of a much more simple structure. By the aid of these formations, the spermatozoa are transferred into the female generative organs. Formerly it was usual to look upon the remains of these bags as the torn-off generative organ of the male. The spermatophora of insects have usually the form of a pedunculated globule (for instance, in the Locustinæ and Lepidoptera). Through a series of transition-forms they reach ultimately the shape of a long thin cylinder, of which a striking example is afforded in Clivina Fossor. The spermatozoa lie either irregularly in the interior of the spermatophora, or united into regular bundles. This mode of grouping has an extremely elegant appearance in the Locustinæ. The tails of the fibres join together on either side of a furrow, from which the several fibres start to the right and left like the barbs from the shaft of a feather. Spermatophora are wanting in many of the Hexapoda. Instead of them we sometimes find (as in Carabæa, Tittigoria, &c.) a number of long and rather broad bandlike transparent strings, which are frequently wound in the shape of a spiral, and, like the spermatophora, are also formed in the vas deferens of the male. These strings, on being treated with water, separate into a great number of spermatozoa, the separation taking place either gradually from the ends, or more suddenly in their whole extent. The entire mass thus proves itself to be one large seminal string, a formation which, in its whole quality, approximates very nearly to the second form of the seminal bundles from the interior of the testicles enumerated by us.

The cause of such an arrangement and grouping of the spermatozoa is equally as unknown to us as that of the formation of the bundles of spermatozoa in the cysts. Whether they are peculiar phenomena of attraction, or whether they are other relations caused by external influences and circumstances, we know not. We must therefore for the present be satisfied with a simple statement of the facts.

Although, from the great uniformity of the spermatozoa in the class of Insects, we might reasonably expect a corresponding similarity in the other groups of the Arthropoda, observation teaches us that such is not the case.

Instead of the filiform formations, which, however, are here the usual constituents of the seminal liquid, there are found in some cases quite peculiar bodies of a remarkable shape. The history of their developement alone can prove that the elements alluded to are not, as one might perhaps suppose, morphologically different formations, but that they owe their origin to a mere modification in the application of the ordinary stages of developement. It can be proved that the bodies in question in most cases are immediately connected with the former stages of developement of the spermatozoa. Thus our conjecture (above expressed) gains in probability, that many of such-like little bodies are mere forms of developement of ordinary filiform spermatozoa. The following investigations, however, will afford us a confirmation of the truth of our conjecture: —

Arachnida. — In the class of the Arachnida, the usual filiform appearance of the spermatozoa has only been observed among the *scorpions.* The spermatozoa of these animals are about $\frac{1}{40}'''$ long, and rather thickened at one end. They develope themselves, according to *Kölliker*, in the usual manner in the interior of vesicles, which are contained, in numbers, in a larger cyst-like cell.

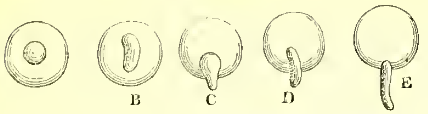
In the *Araneæ*, on the other hand, which, owing to the difficulty of an anatomical examination, have hitherto but rarely been submitted to a careful inspection, the spermatozoa, are said to present a very different shape. *V. Siebold* *, to whom we are indebted for the only statements regarding them, describes them as round or reniform cellular bodies, on the interior wall of which a round or oblong nucleus is situated. We have also met with such corpuscles, and that in great quantity, in the testicles of the most different species of spiders; we must however dispute the assumption of *V. Siebold*, viz. that such are the developed spermatozoa, since we have succeeded in discovering filiform bodies besides these formations, which former undoubtedly develope themselves from the latter, and are the real spermatozoa. These relations we have recognised most distinctly in Clubiona claustraria. The contents of the testicles here consist of a large number of small round cells of $\frac{1}{400}'''$, in which a very perceptible nucleus is contained. The nucleus is at first round (*fig.* 372. A), but gradually elongates

* Vid. Stein.

* Lehrbuch der Vergluchenden Anatomie, § 544.

itself, and then becomes a short, and generally curved, cylinder (B), one end of which

Fig. 372.



Seminal cells in the testicles of Clubiona claustraria.

is frequently club-shaped. The nucleus at the same time generally urges itself towards the outside, its point penetrating through the external cellular membrane. The projecting part of the nucleus generally appears like a protuberance at the margin of the cell, the greater part of it being still situated in the interior (C, D). In some cases, however, it breaks forth in its whole length (E). It then looks like a peduncle-shaped appendix.

We have not been able to discover further stages of developement in the interior of the testicles; but we have succeeded in detecting, besides the already mentioned corpuscles, a number of distinct linear fibres of $\frac{1}{40}'''$ — $\frac{1}{35}'''$ (*fig.* 373.) in the spoon-shaped capsules on the palpi of the males, which, no doubt, were developed spermatozoa. The anterior half of these was generally bent in an arched cylindrical form, and thicker than the posterior tail-like part. Very similar, only rather longer, seminal fibres are likewise found in the seminal capsules of the palpi in a species of Tetragnathus.

Fig. 373.

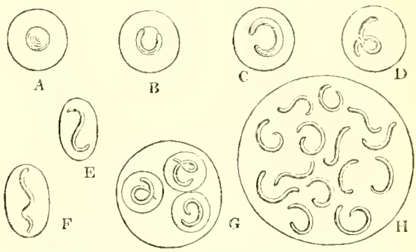
Seminal fibres of Clubiona.

It can hardly be doubted that these fibres have originated from the previously described spermatic cells. The changes of form to which the nucleus is subjected in the course of developement present a gradual approximation to this form of spermatozoa, at least to the form of the anterior thickened corpuscles, with which the nucleus moreover corresponds in its physical characters. In order to render the metamorphosis of the nucleus into spermatozoa complete, it certainly is necessary that the external cellular wall should disappear; but this is a general rule in the developement of spermatozoa, and probably also takes place here, although we cannot furnish any immediate proof of it. It must, however, appear remarkable that we have never met with developed spermatozoa in the testicles themselves. We could only trace in them cells of developement, formations which, besides the spermatozoa, also occur in the capsules of the palpi. The question might be asked whether this would not render the inference justifiable that the spermatozoa only attained their final developement at the latter spot, and therefore at a distance from the place of their formation. From our described observations we cannot yet venture to decide this question with certainty. The circumstance is, at all events, very remarkable, and would be the more so in case *V. Siebold's* statement that the cellular seminal corpuscles are to be met with even in the receptacula seminis of the female spiders, were to receive confirmation.

In our description of the developement of the spermatozoa in Clubiona we have left the question undetermined, whether they originate directly from a metamorphosis of the nucleus, or through endogenous formation in the interior of it. — We have not been able to arrive at any decisive result respecting it with regard to Clubiona, although the latter appeared to us more probable from analogy.

Of some importance in this respect are our observations on the developement of the spermatozoa in a large species of Epeira. The seminal cells measure (*fig.* 374. A) $\frac{1}{200}'''$, the

Fig. 374.



Developement of the spermatic cells of Epeira.

nucleus which they contain $\frac{1}{400}'''$. The cells are enclosed in larger cysts (of $\frac{1}{100}'''$—$\frac{1}{50}'''$); but besides these there is also no want of individual solitary cells.

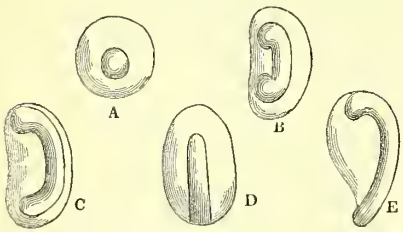
The most interesting circumstance connected with this is, that the spermatozoa are produced quite distinctly in the interior of the nucleus of the spermatic cells. At first they are lying (B) like a bent cylinder at the interior surface of the wall, so much bent that both ends nearly touch each other. We have never perceived a change of shape in the nucleus, nor does the same ever or any where penetrate beyond the cell. It constantly remains round, and in the interior of the cell, until it is dissolved, which takes place pretty rapidly after the formation of the spermatozoa. The spermatozoon now arrives in the cavity of the cell (C—F), where it increases in size (to $\frac{1}{100}'''$). It usually exhibits here some slight and irregular windings, which sometimes change the form of the cell into an oval. The spermatozoon only becomes free afterwards, when the membrane of the cell has disappeared. It is only if the external cyst happens to persist that the spermatozoa still remain enclosed for a time (H), but always in a greater number, which naturally is equal to the number of the cells formerly contained in

it. A tail part we have, however, never been able to discover in the spermatozoa of Epeira. The form was uniformly cylindrical, and of a tolerable thickness, similar to the body in the spermatozoa of Clubiona.

Quite the same mode of developement of the spermatozoa we have also found in one species of Theridimna. It can be traced that it does not deviate at all in the formation of its spermatozoa from other animals. But even the process of developement in Clubiona, which we have described, does not exhibit any very material differences, which is proved by the observation, instituted by us in a small Dysdera, as also in Tegenaria domestica. The mode of formation of the spermatozoa, in fact, in these instances, occupies almost the medium between the former two.

In Dysdera the spermatic cells containing the nucleus (*fig*. 375. A) measure only $\frac{1}{500}'''$.

Fig. 375.



Spermatic cells of Dysdera.

They are round at first until the nucleus elongates itself, enlarges, and finally assumes a kidney form, the external cell taking on the same shape (B, C, D). One end of the nucleus not unfrequently projects outwards (E), but never in so striking a manner as in Clubiona. The same changes of shape are exhibited in the nucleus in the seminal cells of Tegenaria, which measure $\frac{1}{400}'''$; they, however, never lose their original round shape in the course of the change.

We have not been able to discover filiform spermatozoa in the two last-mentioned spiders; but we nevertheless believe that they likewise occur here, as in Clubiona.

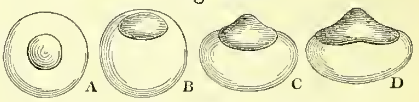
Respecting the spermatozoa of the *Acarinæ*, we have as yet had but few observations; it appears, however, from the statements of *V. Siebold*, that similar stages of developement take place as among the genuine Araneæ. *V. Siebold* observed in the testicles of Ixodes ricinus a large number of rather long and large rods, which had an arched curvature, and were enlarged at one end in a clubbed shape. These rods were probably the developed spermatozoa, and of a similar nature to those we have found in Epeira. We do not venture to determine whether the same inference may be drawn with regard to the club-shaped corpuscles, which *V. Siebold* discovered in the Hydrachneæ and Gamaseæ. From the description given, however, viz. of these corpuscles enclosing an oblong spot in the enlarged end, and of their having been produced by the metamorphosis of round nucleated cells, we would rather suppose that they were mere stages of developement of the seminal cells, similar, perhaps, to the pedunculated seminal corpuscles in Clubiona. In addition to this we may mention that *Dr. Frey* has communicated to us an observation, from which it appears that Hydrachna likewise possesses spermatozoa of a filiform shape.

The contents of the testicles in other Acarinæ (Trombidium, Zetea, Oribatea, Hoplophora, &c.), consist of small globules, which in Bdeila assume a cylindrical shape. We are inclined to consider such as the free nuclei of seminal cells. We, at least, believe we have seen in Phalangium that they were surrounded by a cellular vesicle.

Myriapoda. — The remarkable spermatozoa of the *Chilopoda*, which appear either as cylindrical corpuscles when in a developed state (in Glomeris), or (as in Iulus) as short conical formations with a rounded point, are, according to our observations, of the same nature as the foregoing.

In Iulus terrestris, in which we have traced the developement of these parts through all phases, the primitive contents of the testicles consist of a great number of small round cells of $\frac{1}{450}'''$, containing a very clear nucleus (of about $\frac{1}{750}'''$), which lies close to the cell wall, and is highly refracting (*fig*. 376. A). In the course of the developement, the nucleus en-

Fig. 376.



Spermatic cells of Iulus terrestris.

larges, and, in so doing, gradually converts itself into a short cone (B, C, D), which, with its point, extends beyond the surface of the cell. For a time the cell continues to be attached to the surface, until it dissolves, rendering the seminal corpuscles free (*fig*. 377.). The basal part of the developed

Fig. 377.

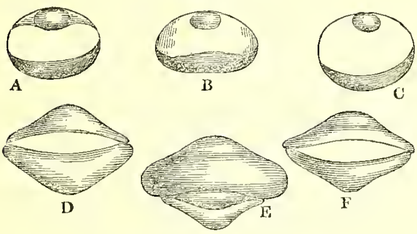
Spermatozoa of Iulus terrestris.

spermatozoa has a diameter of $\frac{1}{500}''' - \frac{1}{400}'''$, and is rather protuberant and enlarged at the edges. The height of the spermatozoa is always less than the width, generally by one half.

On comparing the phenomenon in the formation of these bodies with the first changes of the nucleus in Clubiona, the analogy between the two will clearly be seen. The relative value only of the two is changed. The corresponding conditions in Clubiona form mere stages of transition necessary for further developement, whilst the developement in Iulus does not proceed further than the stage described.

The differences in the form and developement of the spermatozoa of Iulus fabulosus are very interesting. The formation of these parts does not confine itself, as in Iulus terrestris, to the mere metamorphosis of the nucleus into spermatozoa. Previous to the latter projecting over the external surface, the cell membrane gets enlarged on the opposite side (*fig.* 378. A, B, C) into a corpuscle, which assumes the

Fig. 378.



Spermatic cells of Iulus fabulosus.

same shape as the nucleus. The spermatozoa in I. fabulosus do not, therefore, consist in one short cone, but rather in two such formations (*fig.* 378. D, E, F), which are turned towards each other with their broad surfaces partially touching. One of these is not unfrequently distinguished from the other by a more considerable size. In a developed state, when the original cell membrane, in which the cone was formerly imbedded, has disappeared, the two parts sometimes separate, each having a perfect resemblance to the spermatozoa of I. terrestris.

V. Siebold, to whom we are indebted for the first accurate statement respecting the Chilopods *, was not acquainted with the developed forms of these parts in I. fabulosus. He describes as such the stages of developement of the spermatic cells illustrated by us in *fig.* 378. A to E, comparing them with the shape of snuff-boxes, in which the lower surface is much thickened, whilst the upper surface contains in the centre a roundish nucleus.

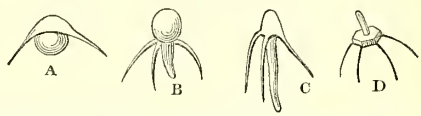
The spermatozoa of the *Chilognatha* † are filiform and of a very considerable length and thickness ; *e. g.* in Geophilus, where they measure $1\frac{1}{4}'''$. Towards one end they gradually become finer, and usually rather undulating or spiral, particularly at the anterior thick part. In Geophilus these fibres are rolled up separately into one ring-like curl ; in Scolopendra, on the other hand, they are straight, and united in small numbers into string-like bundles. Nothing certain is as yet known respecting the developement of these fibres ; but, with *V. Siebold*, we think it very probable that they originate from the larger cells (measuring in Geophilus $\frac{1}{30}'''$, in Lithobius $\frac{1}{20}''' - \frac{1}{15}'''$), which contain a single, double, or treble nucleus (of $\frac{1}{100}''' - \frac{1}{70}'''$) with a nucleolus, and which are found in great quantity in the testicles. From analogy we may infer that it is in the nucleus within the vesicle that the fibres are produced. The association of the groups of spermatozoa in fascicles in Lithobius has, however, no intimate connection with the manner of their production, because the enclosed nuclei never equal in number the united fibres enclosed in one bundle. It is probably the result of a subsequent transition (like the formation of the seminal fibrous strings in the Hexapods).

* Müller's Archiv. 1841, S. 13.

† See Stein. Müller's Archiv. 1842, S. 258.

Crustacea.—Among the Crustacea, to which we now proceed, we likewise meet with, as in the Myriapoda and Arachnida, many varying forms of the seminal elements. The most remarkable are the so-called radiating cells of the Decapods *, small, strangely formed corpuscles of a variable shape (and generally of a size of $\frac{1}{500}''' - \frac{1}{800}'''$), which owe their origin to a metamorphosis of spermatic cells containing nuclei. By the different developement of the nucleus and cell membrane (*fig.* 379. A, B, C, D), they are

Fig. 379.



Radiating cells of Grapsus marmoratus (A), *Pagurus oculatus* (B, C), *and Pisa tetraodon* (D). (*After Kölliker.*)

usually divided into two portions of different shape and size, and are furnished at the boundary between the two with delicate and fibrous rays, which vary in number from one to four, but are generally three ; but this is effected in such a manner that the rays constantly remain connected with the division produced from the metamorphosis of the original cell membrane, and never with the nucleus part.

These radiating cells are produced from the original simple seminal cells in the following manner : — The nucleus (as in Clubiona and the Iulides) gradually projects further and further towards the outside, thereby metamorphosing itself into a roundish (in Calappa, Hyas, Stenorhynchus, Scyllarus, Astacus fluviatilis, &c.) or spiral (in Crangon, Pisa, Galathea, Pagurus) appendix of the cell wall, which frequently enlarges itself considerably, especially in Pagurus, where it reaches $\frac{1}{50}'''$. In the mean time, the cell membrane has likewise undergone some changes. It either gets flattened more or less (Palæmon, Stenorhynchus, Pica, Calappa), or it lengthens itself into a cylindrical corpuscle (Galathea, Astacus marinus). It is sometimes the case, however, that it retains its original round form (Ilia, Pilumnus, Pagurus, Astacus fluviatilis).

At the anterior end of this last corpuscle, where the part containing the nucleus adheres to it, the rays now gradually dart forth,

* Vide the numerous and accurate statements and illustrations of Kölliker.

at regular intervals, which give to the corpuscle sometimes an angular appearance, as in Pisa. The length of the rays holds an inverse ratio to the size of the cells, and is, in most cases, either equal to, or double, their diameter.

The peculiar form of these seminal elements naturally provokes the question, whether they really represent the developed spermatozoa, or whether they are not perhaps mere phases of developement. The relation in which they stand to the simple spermatic cells suggests a conjecture of this kind; and the more so as the rays attached to them already present the greatest similarity with the usual filiform spermatozoa. We regret to say, that we are not yet in a position to decide this question with perfect certainty. From various observations, however, the latter assumption gains in probability. *Kölliker* has observed (in Calappa) that the adhering nucleus is lost at a later period; further, that in Portunus corrugatus, the cell membrane gradually gets very much contracted; whilst, on the other hand, the rays considerably lengthen themselves. If we consider, in addition to this, that radiated cells are found in Ilia Nucleus, which (*fig.* 380.)

Fig. 380.

A cell with rays from Ilia Nucleus. (*After Kölliker.*)

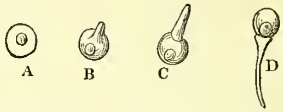
possess extraordinarily long fibres on a very small body; that finally in Pagurus, as it seems, the rays perfectly sever themselves from the corpuscles; that, at all events, developed radiating cells, without rays, are often found in the latter, it must induce us to share *Kölliker's* opinion, that the radiating cells, at this stage of their formation, are not yet perfected; but that they are more likely to be instrumental in the developement of ordinary spermatozoa. Such spermatozoa, however (if we except the genus Mysis, which is certainly unjustly divided from the Decapoda), have not yet been proved to exist in any of the animals belonging to this class. *Kölliker* has succeeded only in Dronia Rumphii in discovering a great number of fine pale fibres of $\frac{1}{100}'''$ in the lowest part of the vas deferens, which probably owe their origin to the rays of the seminal corpuscles, which, however, are much shorter than those fibres, hardly measuring above $\frac{1}{1200}'''$.

Such a negative result can, however, the less determine our judgment on the nature of the radiating cells, since the observations, which one of us (*R. Leuckart*, together with *Dr. Frey*) has instituted, with regard to the developement of the spermatozoa in Mysis, have brought the question pretty nearly to a decision. *V. Siebold* was already acquainted with the filiform spermatozoa in this crawfish, which are distinguished by their great length (of $\frac{1}{3}'''$).

This animal possesses the more interest for us, owing to the remarkable mode of formation of the spermatozoa, which is extremely similar to the developement of the radiating cells in the other Decapods.

The primitive seminal cells in Mysis appear as round pale nucleated vesicles of about $\frac{1}{100}'''$ in diameter (*fig.* 381.). In the course of their

Fig. 381.



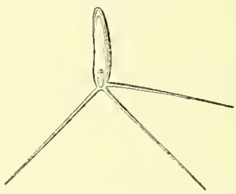
Developement of the seminal corpuscles in Mysis. (*After Frey and Leuckart.*)

further developement, a small wart-like process (B) rises somewhere on this vesicle, which gradually lengthens itself (C, D), and grows into a long cylindrical tube of $\frac{1}{10}'''$. The nucleus does not participate, in any way, in this metamorphosis. It retains its original form, and remains at its original place in the interior of the seminal cell, which is seated on the cylindrical staff like a globular appendix.

In spite of their rather peculiar shape, we do not hesitate to pronounce these seminal elements of Mysis as parallels of the radiating cells of the other Decapods. Excepting the rays, we can find no material difference between them. That the wall of the cell is not immediately metamorphosed into the cylindrical body, is equally as little material as the circumstance that the nucleus remains without change, and does not project outwards. Indeed, we also find the same relation in the radiating cells of Astacus marinus (*fig.* 382.), where the nucleus likewise remains in the interior of the cylindrical radiated corpuscle.

To judge from their form, these seminal corpuscles would have most resemblance to the radiated cells of Pagurus; but, according to Kölliker's observations, it would appear that the long cylindrical appendix has originated

Fig. 382.



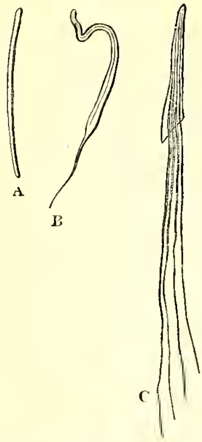
Radiating cells of Astacus marinus (*After Kölliker.*)

from the metamorphosis of the cellular nucleus.

The nucleus in Mysis, together with the surrounding head-shaped part of the seminal corpuscle, is subsequently destroyed, the same as Kölliker has found it in Calappa. There merely remains, then, a simple long cylinder (*fig.* 383. A), which represents the radiating corpuscle. The formation of the spermatozoa takes place in the interior of this cylinder: they consist of long linear fibres, which lie in

it lengthwise, until they perforate the external enclosure at one end, and now gradu-

Fig. 383.



Developement of the Spermatozoa in Mysis.
(*After Frey and Leuckart.*)

ally project outwards (B, C). The number of the fibres thus formed is generally limited to one. We have, however, seen cylinders which contained three or four (C).

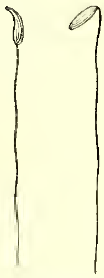
The formation of the spermatozoa in the radiating cells of the other Decapods, in our opinion, takes place in the same manner. Judging from analogy with Mysis, at least, we cannot share the conjecture of *Kölliker*, that the rays would simply drop off and change into spermatozoa. It appears to us much more probable that they are produced, as in Mysis, in the interior of the cell, and that the growing out of rays is merely a secondary event, caused by the circumstance that the spermatozoa formed in the interior urge the external membrane forward with one end, and ultimately penetrate through it. The projection of the seminal fibres, in Mysis, from the cylinder, has indeed much the appearance of their growing out into a thin and long appendix.

Thus much respecting the remarkable seminal corpuscles of the Decapods. We must still, however, mention the circumstance that the radiating cells in the lower division of the testicles, or in the vas deferens, are generally still enclosed by peculiar spermatophora, like capsules, which possess a round or oval shape, and are often attached, by means of a solid peduncle, in great numbers, one behind another, to one common round or flat jelly-like mass.

The spermatozoa in the other orders of the *Malacostraca*, the *Amphipoda*, and *Isopoda*, are uniformly filiform. Their developement takes place in the usual way, without the intervention of radiated cells.

The length of the spermatozoa, in most cases, is very considerable: in Hyperia medusarum $\frac{1}{3}'''$, in Iphimedia obesa $\frac{1}{8}'''$, in Idotea tricuspidata $\frac{1}{10}'''$, in Gammarus Pulex $\frac{1}{30}'''$. The thickness, on the other hand, is comparatively only slight, being most considerable in the centre, whence the fibre gets gradually thinner towards both ends. *Kölliker* describes, in the spermatozoa of Iphimedia and Hyperia, a thicker cylindrical and oval end, like a peculiar corpuscle. *V. Siebold* does the same with regard to Asellus aquaticus. We believe, however, that such an

Fig. 384.



Spermatozoa of Gammarus Pulex.

appendix (*fig.* 384.), or this so-called corpuscle, is merely the adhering remainder of the mother cell, from which the spermatozoa project. Of this we have convinced ourselves in Gammarus Pulex. It is certainly difficult to distinguish the seminal fibre in the interior of it, but it appears to us that our observations are sufficient to render doubtful the interpretation of *Kölliker*, when we consider that this corpuscle occupies so variable a position with respect to the fibre, now lying in the same line with it, and at other times passing into it at a larger or smaller angle, quite in the same manner that we have observed in the cylinder of the seminal corpuscle of Mysis.

The variable shape of the body, which *Kölliker* describes in Hyperia, and which we have also found, although less remarkably so, in Gammarus Pulex, might also speak in favour of our opinion.

The formation of the seminal fibres in the *Oniscidæ*, according to our observation, also takes place in the interior of transparent cells*, which reach $\frac{1}{200}'''$—$\frac{1}{100}'''$, and fill up by their number the sacs of the testicles. As soon as the developement of the spermatozoa has commenced in the interior, the cells grow to the extent of $\frac{1}{40}'''$, and in so doing assume an oval shape. The contents then usually become rather granular, but the windings of the transparent spermatozoa can nevertheless be recognised now and then. The vesicular seminal elements of Gammarus Pulex, on the

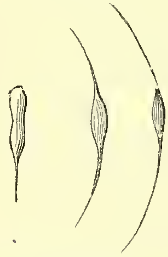
* The large egg-shaped corpuscles (of $\frac{1}{20}''$) which possess, besides nucleus and nucleolus, dark granular contents, and which form the epithelium of the vas deferens, but which are wanting in the genuine seminal tubes, should not be confounded with these seminal cells. Similar cells, only smaller (of about $\frac{1}{200}'''$), are likewise found in the spiders; but, although they occur in the seminal corpuscles of the palpi, they are not in any way connected with the production of the spermatozoa.

other hand, are cell formations, which develope a seminal fibre in the interior of the enclosed nucleus.

Of the same filiform shape, and probably also of the same mode of developement, are the seminal fibres of the *Pychnogonides*, which, according to an observation of Kölliker, measure upon an average about $\frac{1}{50}'''$ in Pychnogonum Balænarum.

Equally filiform and also pointed at both ends, are the developed spermatozoa of the

Fig. 385.



Developement of the Spermatozoa in Chthamalus Philippii. (*After Kölliker.*)

Cirripeds, the size of which, in Chthamalus Philippii, amounts to about $\frac{1}{25}'''$. They are produced from smaller nucleated cells (of $\frac{1}{350}'''$—$\frac{1}{500}'''$), which would seem, from external appearances, simply to grow out into seminal fibres (*fig.* 385.). An exact research into the mode of their production is prevented by the smallness of the cells; but we need the less hesitate in inferring the usual endogenous mode of formation, since we know how often spermatozoa, on liberating themselves from a mother cell, present, in a most deceiving manner, the appearance of vesicles that are growing out.

Little is as yet known respecting the spermatozoa of the *Entomostraca*. Here also, however, the usual filaments occur in the seminal liquid, in some instances. This may be proved in the genus Cypris, in which such formations can readily be traced.* They are of a considerable length (about $1'''$), and usually wrapped up in the shape of a reel. Such a form of the spermatozoa does not, however, seem to be the only one among the Entomostraca. *V. Siebold*†, in Daphnia rectirostris, describes oblong semilunar spermatozoa, whilst Cyclopsina, and probably also Acanthocereus‡, possess small finely granular corpuscles of an oval shape, as the elements of the semen. Similar corpuscles one of us (*R. Leuckart* with *Dr. Frey* §,) has discovered in Caligus. The production of these elements, which could be observed in the latter case, is the same as in Iulus. They at first appear as roundish nuclei in the interior of the seminal cells, which have a size of $\frac{1}{250}'''$—$\frac{1}{200}'''$. At this period the nuclei measure $\frac{1}{500}'''$; they subsequently grow, change their shape to an oval, and in so doing not unfrequently project outwards a little beyond the cell wall.

* We beg to direct attention to the simultaneous appearance of eggs together with the spermatozoa in the same individual; and therefore to the hermaphrodite condition of the genitals in Cypris.

† Vergleich: Anat. S. 483.

‡ According to Schöller, in Wiegman's Archiv., 1846, Th. i. S. 367.

§ Ibid. p. 135.

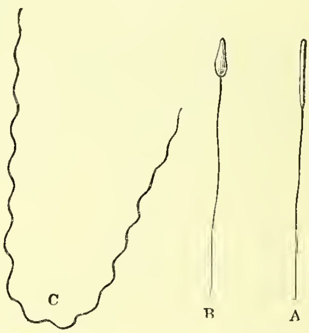
Vesicular seminal elements are also possessed by Branchipus*, and oblong cylindrical corpuscles by Staurosoma.†

In their passage through the vas deferens, the spermatozoa in Cyclopsina, as well as in the Cephalopoda, &c., are enclosed by one common jelly-like spermatophore. In some other cases, on the other hand (as in Oniscus), the spermatozoa unite into long flat ribbon-like strings (of $1'''$), which present quite an uniform structure, betraying at the ends only that they are composed of separate seminal fibres.‡

Annelida.—The spermatozoa, in the division of the Annelida, also possess very generally a hair-like form, excepting among the Nematoda. They are thin delicate fibres, generally without any very considerable length (in Hirudo $\frac{1}{30}'''$, Planaria varicosa $\frac{1}{20}'''$, in Branchiobdella, on the contrary, quite $\frac{1}{6}'''$), which are either pointed towards the ends, or every where equally thick (in the Trematoda, Acanthocephala, and Cestoidea), or enlarged at one end.

In Lumbricus (*fig.* 386. A) the enlarged part is of an oblong cylindrical form; in the Nemertinæ (B) and the branchiated Annelida,

Fig. 386.



Spermatozoa of Lumbricus (A); *of Nemertis Ehrenbergii* (B); *and Planaria verrucata* (C). (*After Kölliker.*)

on the other hand, they are round or pear-shaped. In some few cases the spermatozoa among the Annelida exhibit some spiral twinings; as, for instance, in Planaria verrucata (C), Leptoplana atomata, and especially

* Frey and Leuckart in Wagner's Zootomie, 2d edit. Part II. p. 259.

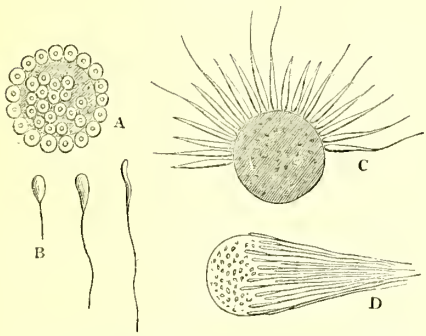
† Will in Wiegman's Archiv., 1844, Th. I. S. 340.

‡ Vide Siebold in Müller's Archiv. 1836.

in the Branchiobdella. In the latter, these windings are, however, confined to the anterior half; but they are so close and numerous that they formerly gave rise to the erroneous opinion of one of us *, namely, that the fibres of this part were jointed or articulated.

These fibres are in all cases produced separately from small cells, containing nuclei (generally of $\frac{1}{500}'''$—$\frac{1}{300}'''$), which lie together in round masses; being generally situated on the circumference of a large central ball among the bristled worms and Hirudines, as among

Fig. 387.



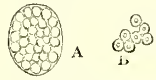
Developement of the spermatozoa in Lumbricus.

the Helicinæ (*fig.* 387. A.). According to analogy with the higher animals the spermatozoa are also unquestionably produced in an endogenous way, and, as is shown by the observations of *Kölliker* † on the developement of the spermatozoa in Lumbricus and Distoma, in the interior of the nuclei. We cannot, however, trace the process of formation with decisive certainty owing to the smallness of the elements in question. The external appearance (B) leads us, however, to infer that the cellular formations grow out into a long fibre. The cells gradually assume a fusiform shape, but still remain united together in one group. It is the peripheric end which seems to get extended in forming the spermatozoa. Wherever a central ball occurs, for instance, in Lumbricus and Hirudo, the group of cells at this stage of the developement presents a very pretty appearance. The spermatic fibres radiate towards all directions from the central ball, into which their thickened extremity is inserted; they have then made their exit in a still imperfect state (C). They soon, however, get grouped together into bundles, the points of the fibres gradually converging towards one common point (D); the central ball in the mean time gradually dissolves. Similar fasciculated groups are likewise seen in the spermatozoa of Annelids in most cases even where the central ball is wanting — in the Trematoda, &c. for instance. The same facts we have already noticed when speaking of the Gasteropoda. We then proved that the separate elements in the groups of cells originate through the continued endogenous formation from one single, and at first simple, cell. It is easily traceable that the same takes place in the Annelida, when we compare the different constituents of the semen, for instance, in Lumbricus. Here, as in the Gasteropoda, we meet with numerous formations, which in one continued series of transitional developement lead to the form of groups of cells, taking their origin from one single nucleated cell containing some brownish granules. In the interior of this cell numerous daughter cells are produced, the number of which continually increases. Finally the wall of the mother cell bursts, the enclosed cells become free, and deposit themselves around the remainder of the cellular contents, which latter have not participated in the formation of the daughter cells.

Whenever the central ball is wanting in the group of cells, the mother cell generally gets destroyed at an earlier period. This view is supported by an observation of *Kölliker*, from which it appears that the groups in Spio consist at first only of few and large cells, which subsequently increase in number whilst their size decreases. It is impossible, however, to draw a very strict boundary here. Even in the former case the increase of the daughter cells frequently seems to take place after the membrane of the mother cell has been destroyed, which may also be seen in the Helicinæ. In other cases the mother cell not only survives the endogenous formation of daughter cells, but also the process of the developement of the spermatozoa. We are at least led to this inference by the observations which we had the opportunity of making in some small species of Terebellaria from the North Sea, namely, that the bundles of spermatozoa are sometimes still enclosed by one common oval cyst.

Bryozoa.—A similar series of phenomena we

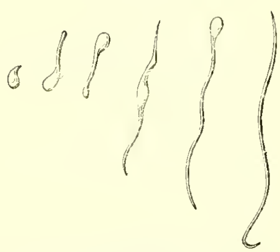
Fig. 388.



Spermatic cells of Flustra carnosa; (A) *still contained in the mother cyst;* (B) *partially free.*

find in some Bryozoa (which would be perhaps

Fig. 389.



Developement of the spermatozoa of Flustra carnosa. (*After Kölliker.*)

most correctly classed among the Annelida), for instance, in Laguncula and Alcyonella*,

* Wagner in Müller's Archiv. 1835, S. 222.

† Kölliker, Die Bildung der Samenfäden, u. s. w. S. 37.

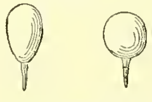
* Vid. Von Beneden in the Mém. de l'Acad. de Bruxelles, tom. xv. and xviii.

whilst the formation of the spermatozoa in others (for instance, in Flustra, Erisia, Bowerbankia) only commences when the separate cells of developement (B) have become free through the destruction of the large ($\frac{1}{100}'''$—$\frac{1}{70}'''$) cyst-like mother cell (*fig.* 388. A.). The spermatozoa even here, however, are produced by the apparent growing out of the small cells of developement (of $\frac{1}{500}'''$) containing nuclei (see *fig.* 389.). When developed they are linear and proportionately thick and long (in Flustra about $\frac{1}{25}'''$), and frequently, it seems, furnished with a roundish or oval corpuscle.

Rotifera—The spermatozoa of the Rotifera, at least of Megalotrocha, have a similar pin-like form, if we may judge from the observation of *Kölliker* *, which is the only one before us, and this does not seem to be quite decisive. His statement, that these formations had partially been fixed in the interior of the cavity of the body, makes us at least look upon his observations with mistrust, and leads us to suppose that they have been confounded with the remarkable vibratile organs, which are certainly not spermatozoa. *Kölliker's* observation, however, is interesting, inasmuch as he also states that those fibres are apparently produced through the growing out of small solitary cells.

Spermatophora have not yet been met with in the division of the Annelida. On the other hand, however, we have observed that the spermatozoa in some species of Sænuris (Tubifex) unite into transparent homogeneous strings (as in many insects) in their passage through the vas deferens. These formations have a cylindrical shape, almost vermicular, getting thinner towards both ends. They are also not unfrequently met with in the receptaculum seminis of the female apparatus. A similar mode of grouping seems to take place with regard to the spermatozoa of the Hirudines, in the so-called secondary testicles. The spermatozoa of the Nematoda (excepting the paradoxical genus Pentastomum, in which we find the ordinary linear spermatozoa) possess very deviating shapes. They consist of a roundish or oval corpuscle of about $\frac{1}{300}'''$, and a short rigid peduncle, which projects more or less outwards, and has a varying thickness (*fig.* 390.). The spermatozoa in

Fig. 390.



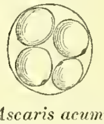
Spermatozoa of Strongylus auricularis. (After Reichert in Müller's Archiv. 1837. Tab. VI.)

Gordius appear in the shape of short rods without any corpuscles.

We cannot doubt that these seminal elements are developed spermatozoa, having sought in vain, and for a long time, for other forms of developement, and having found the very same formations again, in a perfectly unchanged shape, in the female individuals. We must therefore characterise *Kölliker's* supposition of these corpuscles being mere stages of developement of seminal fibres, as one that cannot be relied upon.

The developement takes place in the same way as in Iulus. At first we find simple cells containing nuclei, which, according to *Reichert's* researches, are produced in the interior of large mother cells * (*fig.* 391.). The nucleus

Fig. 391.



Spermatic cell of Ascaris acuminata, with four vesicles of developement. (After Reichert.)

has at first a roundish shape (*fig.* 392.), but gradually stretches itself more and more, and

Fig. 392.

Developement of the spermatozoa of Ascaris acuminata.

projects more or less outwards with its point, thus metamorphosing itself into the peduncle-like appendix of the spermatozoa, the body of which is formed from the persisting membrane of the seminal cell. This last circumstance, but which does not invariably occur, is the only distinction that can be found between the Nematoda and the Iulidæ.

RADIATA. — *Echinodermata.* — The spermatozoa, in the division of the Echinodermata, possess, it seems throughout, a pin-like form (*fig.* 393.), with a small

Fig. 393.

Spermatozoon of Holothuria tubulosa.

roundish body (of $\frac{1}{600}'''$), and a very slender tail appendix of about $\frac{1}{70}'''$—$\frac{1}{50}'''$. It is only in rare cases (as Spatangus) that the body has an oblong form, and is rather pointed at the anterior end.

The developing cells of these spermatozoa are very small, and lie in groups, as in the Bryozoa, inclosed in large cyst-like mother cells. The developement of the spermatozoa undoubtedly takes place according to the usual mode, although it cannot be proved with certainty, and although the appearance

* Froriep's Neuen Notizen, S. 596.

* Müller's Archiv. 1847, S. 88.

seems rather to indicate a gradual elongation of the cells. The spermatozoa lie together in bundles, either enclosed by the cysts or free.

Acalephæ and Anthozoa.—The Acalephæ and Anthozoa exhibit quite a similar series of phenomena. The bodies of the spermatozoa are usually round, frequently however, especially among the Medusæ (*fig.* 394.), oblong, cy-

Fig. 394.

Spermatozoon of Pelagia denticulata.

lindroid. Little is as yet known respecting their developement. The spermatozoa have generally a fasciculated style of grouping together, and mostly so at a period when they are still enclosed by cyst-like cells. Previous to the maturity of the generative capacity, these cysts contain, as has been proved with regard to the Medusæ, numerous small vesicles, which subsequently pass through apparent prolongation into spermatozoa.

Infusoria. — The Infusoria are especially distinguished by the want of a sexual mode of propagation. There is no trace of either spermatozoa or ova to be discovered in them. *Ehrenberg*, it is true, describes in these animals particular organs of procreation, both male and female; but there is no foundation for the assignment of such an import to these particular parts of their structure, it being altogether an arbitrary one. The proof of the existence of spermatozoa and ova — the characteristic structures — is indispensably necessary to prove the embryo-preparing function of certain parts, and to justify their being interpreted as generative organs.

General conclusions respecting the morphology and developement of the spermatozoa. — A review of the description now lying before us, of the form and developement of the seminal elements in the several divisions of the animal kingdom, and of the mutual relations of the respective formations, must unavoidably lead us to claim for them a different morphological value.

By far the greater part of the spermatozoa, — all the so-called seminal fibres, which are distinguished by the linear form of the body,— are produced in an endogenous way, and that (with the exception of the spermatozoa in the Decapoda) separately in the interior of vesicular elements. *Kölliker* * was the first who directed attention to the wide extension of this mode of production †, having claimed it likewise for such animals, in which appearances are rather in favour of an immediate metamorphosis of the vesicles of developement into seminal fibres (by means of elongation, growing out, &c.). The laws of analogy certainly justify us in drawing the same inference as *Kölliker;* the more so, as observation has proved that many animals, the developement of whose spermatozoa was formerly accounted for by the latter methods, evidently also follow the endogenous type.

It is difficult to trace the intimate developement of the spermatozoa in the interior of these vesicles; but it appears probable that it is brought about by the junction of molecular corpuscles, which join each other linearly, and which have been deposited from the contents of the vesicles. Indeed, such a mode of procedure does not seem to be at all singular in the history of developement of organic tissues. By saying this, we do not exactly mean to allude to the mode of formation of the muscular fibrils in the interior of the sarcolemma of a so-called primitive fasciculus, since at present we know too little about it; yet, we cannot help reminding our readers of the process of lignification in the vegetable world, or of the production of the so-called spiral vessels, which essentially seem to be founded on a perfectly analogous deposit of a firm substance, from that which was at first fluid.

The decision of the question respecting the histological significance of the vesicles of developement is much more difficult. In many cases, especially when they are situated separately or in small numbers in the interior of the spermatic cells, they have evidently the value of nuclei. Whether this however is always and every where the case, as *Kölliker* supposes, we would not assert; the less so because the appearance and the vesicular form of these structures do not by any means enable us to distinguish them properly from cells void of nuclei.

By the laws of analogy, we are, however, perhaps justified in forming a judgment on the nature of the respective elements even in such doubtful cases. We ourselves might perhaps even venture to pronounce that the vesicles of developement of the spermatozoa are in all cases nuclei. The unity in the mode of developement of the spermatozoa which would thus be established is certainly very attractive; but we dare not conceal it from ourselves that this inference from analogy is the less to be depended upon, since the genesis of the spermatozoa in the Decapoda furnishes us with a proof that the formation of these elements may also take place immediately in the interior of cells, without the nuclei at all participating in it. We are confirmed in this opinion from the circumstance that in many Decapoda, for instance in Mysis, it is not the cell itself in which the spermatozoa are produced. The cylindrical

* Die Bildung der Samenfäden.

† The doubts which Reichert recently raised against the correctness of the statements and observations of Kölliker we certainly must consider as entirely unfounded.

staff, in the interior of which the spermatozoa are developed, is the produce of the metamorphosis of this cell; a metamorphosis which here appears in its extreme form, but which in other cases is less striking, and may even be entirely wanting. And then it is the cell in its unchanged form which appears as the vesicle of developement of the spermatozoa.

Under such circumstances it might for the present be venturing too much to sever the mode of developement of the spermatozoa in the Decapoda, as a particular form, from the ordinary endogenous formation of these elements. We are not justified in so doing, until we have proved that in other animals mere nuclei exist as the mother cells of the spermatozoa. It is possible that such a proof may yet be established, indeed even probable, when we consider that there is also in other respects a difference in the formation of the seminal fibres between the Decapoda and other animals, inasmuch as the vesicles of developement in the former generally and almost constantly produce a greater number of spermatozoa, whilst in other animals they only produce a single fibre.

As a circumstance of subordinate import, which need not influence our judgment respecting the nature of the vesicles of developement, we may specify a difference in the histological characters of these parts, which certainly at first sight must appear very striking. We meet with them either in an independent free state, or separate, or enclosed in a variable number within cells, which themselves not unfrequently hang together in groups, or are even situated in a cyst-like enclosure. But all these differences result solely from a different developement and application of all the plastic capacities inherent in the cells. They are due to the occurrence of an endogenous multiplication, and are readily explained by the intimate unity and connection which this method of developement presupposes.

The formative elements of the semen appear to us in their primitive form as simple nucleated cells. But it is only rarely that they retain this original form. As a rule they present only the starting point of a series of metamorphoses, which essentially are limited to a new formation of nuclei, or even of perfect nucleated cells in the interior of the primitive spermatic cell: a new formation, which, however, not unfrequently occasions the destruction of the mother cell.

It is not yet decided in all cases in what manner the formation of the daughter cells takes place, whether in the usual mode of endogenous cell formation, or by enclosure of portions of the contents. It seems, however, that the former mode of production is by far the more frequent one. *Reichert* has been the only one who has hitherto discovered a formation of daughter cells round portions of the contents (like the formation of cells in the minutely divided yolk) in the spermatic cells of the Nematoda. If such discovery should be confirmed — should it even have a greater extension — we may then further presume (as Kölliker already observes) that these two modes of developement are not essentially different from each other.

The description we have just now given may, at all events, be sufficient to prove of what a merely subordinate significance are these differences in the histological arrangements of the formative elements in the seminal fluid. By a series of intermediate stages, we can almost every where readily trace the connexion in which the arrangement of the vesicles of developement stands with the simple primitive spermatic cell. Such a relation, however, is not only interesting on account of its enabling us to recognise an internal *typical* structure and developement of the seminal contents, and that in spite of their external variety, but also because we thereby discover that the primitive form of the male procreative elements is precisely the same — namely, a simple cell — as that of the female generative product, which is designated "the ovum."

Having thus, by our preceding researches, arrived at the result that the developement of the spermatozoa always and everywhere originates from the same primitive formation, namely, from the simple cell, another question now arises, viz. the question respecting the relation of this simple cell to the epithelial lining of the seminal tubes.

This claims our attention the more, as our conception of the epithelium, within a recent period, begins to be more and more indefinite, owing to the accumulation of observations, by which the so-termed epithelial cells of the glands have been proved to be mere vesicles of secretion, the workshops for the preparation or expulsion of the products of secretion.

The recognition of the connexion of the spermatic cells with the real epithelial cells is rendered very difficult by the various metamorphoses of the former in the tubuli seminiferi. Nevertheless, some observations that have been made may perhaps already justify the inference that the simple spermatic cells are, in many instances, at least, identical with the so-called epithelial cells of the seminal tubes.

This appears with particular distinctness in the Gasteropoda, in which *Meckel** and *Kölliker* have already assumed such a relation, without, however, pronouncing it with that degree of certainty which our observations enable us to do. We may as readily convince ourselves of this fact in the Annelida, in Hirudo or Ascaris, as also in the Insects, Spiders, and Arthrostracans: it being evident in all of them that the spermatic cells constitute the only vesicular contents of the testicles, and form, in their primitive shape, a complete epithelial layer, the elements of which frequently even assume a polygonal shape by close adaptation to each other.

* Muller's Archiv. 1844.

This connexion is, however, least distinct among the higher Vertebrata; in which, independently of the spermatic cells which exist free in the semen of the seminal canals, there likewise occurs a special and generally well developed stratum of epithelial cells, which are distinguished from the former by size and appearance. But this arrangement is only to be met with during the period of generative maturity. Previous to it, free spermatic cells do not exist, and the canals of the testicle have then uniform contents, consisting of small cells of $\frac{1}{300}$ of a line in diameter, in which one or two small granules are contained. We have not been able to trace the history of the real seminal cells, but we do not consider it as altogether improbable that they are produced from the former epithelial cells, and most likely are developed in an endogenous manner. The possibility can certainly not be denied, that they may have been produced independently and free in the interior of the seminal canals. But even in this latter case it is unquestionable that the vesicle in which they develope themselves is furnished by the epithelial cells and has formerly been contained in their interior. The difference even in this instance, therefore, would not be so very material, and might be reduced to a mere difference in the periods of formation. In both cases the seminal cells might be assumed to be produced from the contents of the epithelial vesicles, either at a period when such contents are still contained in the interior of them, or after they have become free.

Our preceding remarks respecting the histological relations of the seminal cells apply in an equal measure to all animals, and not merely to those the spermatozoa of which possess a linear form and are produced in the interior of the vesicles of developement. The Chilopoda, Acarina, Entomostraca, and Nematoda furnish us with sufficient proofs of this, — proofs which contradict the assumption of *Kölliker* *, that a linear form of spermatozoa is common to all animals. Although many of the differently-shaped seminal elements may, after a more accurate research, be proved to be mere forms of developement of the real spermatozoa, even this cannot be asserted with regard to all of them. These differently-shaped seminal elements are the very ones that here more particularly concern us; we know that they differ in their developement from the ordinary seminal fibres. They are solid massive corpuscles, which, as we have already shown, have been produced simply and immediately from a metamorphosis of nuclei.

But even here it is the nuclei of the seminal cells, which serve for the developement of the spermatozoa. The whole difference consists in this, that the nuclei are metamorphosed altogether into the fructifying elements of the semen, whilst otherwise they produce the spermatozoa in the interior, they themselves getting dissolved when the latter are about to be liberated. The external cellular membrane which encloses these nuclei remains, however, without any immediate participation in the formation of the spermatozoa. It gets destroyed in the course of the developement, in order to enable the nuclei, which in the mean time have been converted into spermatozoa, to make their exit. This at least holds good in most of these cases, the Nematoda only being an exception. The membrane of the cells belonging to the metamorphosed nuclei, persists in the latter-named animals.

According to this we have a threefold mode of developement of the spermatozoa, viz.: —

1st. The cell membrane and nucleus of the formative vesicles convert themselves immediately into the spermatozoon.

2d. The nucleus of the formative vesicles alone metamorphoses itself into the spermatozoon.

3d. A new formation, which takes place in the interior of the nucleus (or immediately in the cell cavity), performs the functions of a spermatozoon.

On comparing the spermatozoa developed in these different ways, we cannot deny that they have a different stage of developement in a morphological point of view. The spermatozoa resulting from endogenous formation are most highly developed; they are the produce of a perfectly new generative process, whilst the other forms of spermatozoa owe their origin to a persistency and further developement of structures, which, first of all, were mere transitory elements, and were only of importance as the seat of that neoplastic process. Under such circumstances we may assume, then, that all these forms of spermatozoa, according to the morphological relation in which they stand, are mere different stages of developement in one common continued series,—mere variations of one thema, in which the differences seen are not essential, but only of a relative import. Taking into consideration this unity, we cannot agree to the objection that may possibly be made to us, as if we had described the spermatozoa (which, essentially and in fact, are identical formations) to have been produced in different ways. The mutual relation of these differences is in perfect unison with the laws of organic architecture, which every where (when a common plan is made the basis of a series of formations) exhibits the variety of the concrete form principally through a variable developement and perfection of the ideal type.

It might not be without interest to reflect upon the important part which the nucleus plays in the formation of the spermatozoa, since it is an element which is usually only important for the formation of cells, and does not participate in their subsequent metamorphoses. This at least is the rule; a rule, however, by no means without exception. We already know that in many cases the nucleus is important for the developement of certain parts; we know that the nucleus

* Page 63.

in many glandular cells of the insects gradually assumes a remarkable ramified shape*; and that it even converts itself in other cases into peculiar fibrous formations — into the so-called nuclear fibres (Kernfasern).† Still more remarkable is the metamorphosis of the nucleus in the developement of the so-called prickle or nettle organs — those interesting microscopical formations, which are so frequently imbedded in the skin of the lower animals (*e.g.* Polyps and Medusæ), and which present so great a similarity to certain forms of the seminal fibres, that they were even taken for such by one of us on their first discovery. *Kölliker's*‡ observations, as well as our own more recent ones, instituted upon Hydra, convince us beyond doubt that it is the nuclei of cells which gradually metamorphose themselves into the capsules of the prickles, and which ultimately become free through the dissolution of the cell membrane surrounding them. The same genetic process therefore takes place here in every essential point of view, as that by which the formation of the spermatozoa in the Chilopoda is effected. But the developement of the prickles is never limited to this metamorphosis of the nucleus. There is formed at the same time in its interior a peculiar linear or fibrous part, which however constantly enters into combination with the persistent external vesicle of the nuclei or with the capsule. Thus we may see that the formation of the prickles is closely connected with that scheme which we have laid down as a formula for the developement of the spermatozoa. It occupies the medium between the second and third mode of developement of the spermatozoa established by us.

On examining the external coverings of Hydra, we shall readily be enabled to convince ourselves of the formation of these organs. The most different stages of developement may here be seen, viz. developed prickles, either free or still enclosed by a cell membrane, from which the organ itself, and especially the fibre enclosed in its interior, recedes more and more, until it finally appears as a mere simple nucleus. In several Planariæ the organs are contained, in an imperfect state, in considerable numbers in one common cell. The nuclei in the interior of the cells have therefore multiplied here, as in the seminal cells of the vertebrata.

Organization of the spermatozoa. — At the period when the spermatozoa were still considered as individual animated creatures, it was natural that those qualities should be sought for, which distinguish animals generally; and it was frequently asserted that the distinct traces of an internal organization had been found in them. Even *Leuwenhoek**, the oldest observer of these structures, describes in the body of the spermatozoa of the ram and of the rabbit, indications which were subsequently interpreted by *Ehrenberg*† and *Valentin*‡ to be intestines, stomachic vesicles, and even generative organs. Other histologers, for instance, *Schwann* and *Henle*, thought themselves justified in calling a dark spot, which shows itself occasionally in the body of the spermatozoon in men, but which is decidedly a mere accidental formation, as a suctorial cavity. But all these statements are now no longer believed in, as our present knowledge of the developement of these formations has entirely removed the idea of their parasitic nature. Indeed the subject requires no further refutation, as an unprejudiced observation will prove that the spermatozoa are every where void of a special organization, and consist of an uniform homogeneous substance, which exhibits, when examined by the microscope, a yellow amber-like glitter. The above mentioned investigators have by this time undoubtedly seen their error.

Motions of the spermatozoa. — The opinion of an internal organization of the developed seminal elements was not a little supported by the various remarkable phenomena of motion, which were frequently perceived in them. In former times, when people had no idea of the existence and extent of the so-called automatic phenomena of motion, which take place without the intervention or influence of the nervous system; when nothing was known of the motion, very similar to a voluntary one, which exists even in plants; this movement was certainly calculated to place the independent animal nature of the spermatozoa almost beyond a doubt. But it is different now. We now know that motion is not an exclusive attribute of animals, and that an inference respecting the animal nature of the formations in question, however similar the motion observed in them may be to that of animal organizations, is a very unsafe and venturesome one. We know that certain elementary constituents, animal as well as vegetable, possess a power of movement, and that they even retain it for some time after having been separated from the organisms to which they belonged. We only here need remind our readers of the so-called ciliated epithelia, the severed cells of which swim about in the fluid surrounding them, and which, when in this state, have not unfrequently, and that even quite recently, been considered as independent animals§; how,

* According to the discovery of Frey and Leuckart (Wagner's Zootomie, ii. p. 61.), which subsequently, has also been made by H. Meckel (Müller's Archiv. 1846, S. 26.).

† Vid. Henle (Allgemein. Anat. S. 193.) and Zwicky (Metamorphose der Thrombus).

‡ R. Wagner in Weigmann's Archiv. 1835.

* Opera, vol. iv. pp. 168. 284.

† Infusoriensthierchen, S. 465.

‡ Nov. Act. Acad. Leopold, vol. xix. p. 239.

§ For instance, Nordmann, has described the severed ciliated cells from the sails of the larvæ of Nudibranchiata as parasitic Infusoria (Cosmella hydrarhaoides). (Versuch einer Monographie der Tergipes Edwardsii. Petersburgh. S. 97.)

further, the spores of the algæ possess motion by the aid of a ciliated investment *, or of a single or manifold long whip-like fibre, until they eventually become fixed, and develop themselves into a new plant.† Such spores as these may be found described and illustrated in the well-known magnificent work of *Ehrenberg*, classified as Infusoria under the groups of Monadina, Volvocina, &c.

Under such circumstances we may consider ourselves perfectly justified in declaring every attempt to prove the parasitic nature of the spermatozoa, by the characteristic of their peculiar motions, as futile and inadmissible. Developement, structure, and composition are the decisive characteristics in this respect, and these prove the fructifying elements of the semen to be mere elementary constituents of the body in which they are formed. The motions of the spermatozoa are therefore in their essence identical with the above mentioned automatic motions of cilia, &c. But the knowledge of the movement of the spermatozoa will always be interesting and important; because, of all these phenomena, it is undeniably most closely connected with the locomotive motions of animals.

We must not, however, lose sight of the fact, that these motions are not possessed in equal perfection by all spermatozoa, but that in many cases they are scarcely visible, and hardly equal the motions of the cilia. Indeed there are many spermatozoa which are perfectly motionless, particularly all those forms which owe their immediate origin to a metamorphosis of the nucleus, or of the wall of the primary cells. Only those spermatozoa which have been produced by an endogenous and new developement are capable of independent motions, and even not every one of these. No such movements have as yet been perceived in the spermatozoa of the Malacostraca (Isopoda and Amphipoda). They appear motionless and rigid. The same holds good with regard to the body of the spermatozoa when it has a short, round, or pyriform shape. It never then participates in the motions, which are in such cases altogether effected by the thinner, whiplike, caudal extremity. It is different, however, with those spermatozoa which possess a cylindrical body. The body here participates in the motion; at least very frequently, as, for instance, among the scaly amphibia, among the birds (excepting among the singing birds), &c. But the motions of the body are less rapid, energetic, and various than those of the tail. They are principally limited to a bow-shaped curvature, similar to the motion of the Vibriones, which, like the Monadina, belong to the vegetable kingdom, and may undergo a further developement into fibrous fungi.

* Vid. Unger, Die Planze im Moment der Thierwendung; also Von Siebold, Dissert. de Finibus inter Regnum Animale et Vegetabile constituendis.

† Fresenius, Zur Controverse über die Verwandlung von Infusorien in Algen.

In order to observe the movements of the spermatozoa properly, they ought to be investigated under different circumstances. On putting a drop of thick semen from the vas deferens under the microscope, a slow motion only can usually be observed in the accumulated masses of spermatozoa. They present an appearance as if they had some difficulty in disentangling themselves from the tough fluid by which they are surrounded. On adding blood serum to it to dilute the mass, the movement becomes more lively, either instantaneously or gradually. Separate spermatozoa writhe once or twice, turn round on their axis, lash with their tail, and creep about in all directions over the field. The motion gradually imparts itself to greater numbers. Here and there, simultaneously all the individuals of a group begin to move; or particular parts of the mass commence the movement. The remainder perhaps exhibit no motion, and sometimes this quiescent state is permanent.

If the movement of the spermatozoa be rapid, it assumes, for the most part, an accurate rhythm like a pendulum. The filiform tail vibrates like a whip, and the small corpuscle or head follows the impulse. Frequently a peculiar trembling, dancing, or jumping is exhibited by the latter when the rest of the spermatozoon remains fixed and unmoved. A serpentine creeping in all directions is produced during a slow motion, and is caused by an undulating contraction of the caudal appendix. These undulating motions are perhaps the most frequent which the spermatozoa (and even the thread-like forms which possess no visible body) present to our view. They often move in one straight direction, without turning aside, and altogether in such a way and with such a regularity as to resemble the locomotive motions of many of the lower animals.

The same regularity is met with in the motions of the long and rigid spermatozoa with a spiral body among the singing birds, which very frequently turn rapidly round their axis, and thereby advance with a screw-like or boring movement. Pendulum-like lateral motions are but rare.

Very peculiar and different are the motions of the spermatozoa in the Salamanders, which usually lie wrapped up like a watch spring, flat on a level. For a time they remain quiet until suddenly, by fits and starts, a trembling motion takes place, by which they turn themselves round in a circle, pretty nearly on the same spot. Some few (as the Bombinator) stretch themselves out, and travel with a slow undulating motion over the field of the microscope. The most remarkable phenomenon, however, consists in a peculiar wavelike motion on the surface, and which is solely caused by the rapid succession of undulating motions. We have also perceived a perfectly similar undulating motion in the very long, coiled-up spermatozoon of Geophilus, which is occasionally so powerful as

to cause the whole fibre to be moved round in a circle.

The normal movements of the spermatozoa just described must be distinguished from various other remarkable and irregular phenomena of motion which are perceived on treating them with water, particularly in the long and hair-like spermatozoa of the Insects, Gasteropoda, Helmintha, and Cirripeda, and also sometimes, although in a slighter degree, in those of the Reptilia and Mammalia. *Siebold** was the first who estimated these latter phenomena at their proper value, attributing to them their real cause, viz. the hygroscopic quality of the spermatozoa.

These phenomena take place only on the addition of fresh water, whilst sea water exercises but little influence on the spermatozoa, which may be accounted for by the difference in the saline constituents of these fluids. This fact, however, is of the greatest importance, in a physiological point of view, because the fecundation of the ova in many marine animals does not take place by copulation, but is accomplished through the transfer of the spermatozoa by means of the sea water, and the influence of this medium should not be such as to destroy the power of motion on the part of the spermatozoa. In cases where the fecundation takes place in the same manner in fresh water, for instance in the muscles, the spermatozoa are but slightly hygroscopic, so that their integrity remains undisturbed.

These abnormal phenomena of motion, caused by the influence of water, exhibit something similar to that which is seen in a rope turned by a wheel in a rope yard. The spermatozoa roll themselves out in larger or smaller windings, and form simple or compound coils of the most variable kinds. Frequently they turn back again after some time, and re-assume their original shape; they frequently also remain in the position they have at first assumed. In short, changes take place every moment. When the fibres lie in a straight position, a number of coils are suddenly produced; but they disappear equally as quickly, and it is only after some hours, when all the spermatozoa have rolled themselves into these coils, that the movements finally cease.

It is interesting that the normal undulating motions of the spermatozoa, where they lie together in regular masses without being able to change their position, very frequently coincide in a remarkable manner, appearing to be carried out, as it were, by one common will. But although this may appear strange at the first glance, it cannot surprise us when we consider that the same behaviour is observed in the ciliated cells. We here see the motions in the cilia of one epithelium regulated, as it were, by one common plan; we observe how these coincide with the movements of the cilia of others, and thus unite into one regular motion of the whole. A peculiarly beautiful sight is afforded by the aggregate motion of the spermatozoa in the semen of the earth worm, which resembles the undulating motion of a corn field. Among the insects we have also various opportunities of observing this kind of aggregate motion.

A similar aggregate motion is frequently (especially among the Invertebrata) found in the separate bundles of spermatozoa, even when they are still surrounded by their cyst-like enclosures. At first sight it creates an impression as if an undulating fluid were agitated in the interior of the cysts, whilst it is merely the winding motions of the spermatozoa, which follow each other in quick and regular succession, imparting the impulse to the whole mass.

Motion, however, is entirely wanting when (as is especially the case among the insects) the spermatozoa are united into simple and uniform cords. A slight curving or trembling is only observed now and then, which is evidently the consequence of hygroscopic conditions.

We know as little of the cause of the movements of the spermatozoa as we do, in point of fact, of the remote cause of every motion. But that it depends on certain relations of structure and composition, is evident from the circumstance, that it is wanting in the undeveloped spermatozoa, only gradually taking place with progressive developement. A slight vibration or beating with the tail is first of all observed in them. The most lively, most vigorous, and most combined motion takes place, on the other hand, during the period of rutting, when the developement of the fructifying spermatic elements has reached its height.

But the motion of the spermatozoa is not even then unlimited. The death of the animal in whose spermatic organs they are contained, or their removal from it, only allows the motions of the spermatozoa to survive for a time, which, however, is of a different duration in different animals. It seems to be shortest in the birds, where the motion frequently is extinguished fifteen or twenty minutes after death; at least it can but rarely be observed after some hours. In the mammalia their motion survives some time longer, especially if they remain enclosed in their natural organs.

Death, or removal, seems to have a different influence on the spermatozoa of the cold-blooded animals; among the fishes, for instance, they continue moving for days after having been expelled from the body. The mode of death of the animals has no influence at all upon the duration of the motion in the spermatozoa. It remains all the same whether the animals are decapitated, strangled, or poisoned.

The motion of the spermatozoa survives longest of all in the interior of the female generative organs. The insects (in whom, as in Gasteropoda and some other animals, particular pockets or capsular organs are developed during the period of procreation) furnish

* Müller's Archiv. 1836, S. 19.

the most striking proof of this. The spermatozoa, when enclosed in these, frequently retain their full vitality for months. Among the mammalia, likewise, the motions of the spermatozoa remain unimpaired in the vagina, or in the uterus, for some days after copulation.

The mucous coat which covers these organs has no prejudicial effect on the motion and vigour of the spermatozoa*, and equally as little so the addition of other animal fluids, as the secretion of the prostate, the serum, milk, &c. Common saliva, and even bile or pus, does not exercise any impeding influence upon the motions of the spermatozoa.

The addition of urine, especially when having an acid reaction, seems to have a rather more injurious influence upon them, for their motion ceases soon afterwards, although for some hours slight traces of it may still be perceived.

We have already treated of the influence of common water upon the spermatozoa. Diluted saline solutions or sugar and water, on the other hand, either do not produce these injurious effects at all, or, at least, only in a very slight degree. The chemical agents are the only ones which have a positively injurious effect on the spermatozoa, changing and destroying their structure and composition; as for instance alcohol, acids, metallic salts, &c. Diluted aqueous solutions of narcotic vegetable substances, of strychnia, morphia, &c., have the same effect as common water.

The electric spark destroys the motion of the spermatozoa instantaneously, unquestionably because it changes their structure. Galvanism, on the other hand, remarkable to say, has no effect upon them, as *Prevost* states. A high or low temperature likewise causes the motions to cease, or at least to slacken, although the motions of the spermatozoa of frogs and fishes continue when the surrounding medium sinks below zero. The same has been observed in the spermatozoa of Limnæus and Planorbis on treating them with hot water of 70°—80° (Centigrade).

Chemical composition of the semen. — The semen in most animals is a tough, thick, white, yellow, or darkish grey fluid, heavier than water, falling to the bottom when shaken with it. Its taste is sharp and astringent. The peculiar smell, which is usually attributed to it, is comparable with the smell of bone filings, and has its origin, perhaps, in the secretions mixed with it. Pure semen in man and animals does not seem to give forth any decidedly striking smell.

The chemical analyses of semen are dated from a period when our knowledge of organic combinations was still very imperfect, and far from having attained that elevation, by which it has become equally important to physiology as the study of morphology. The works of *Fourcroy, Vauquelin, Jordan, John,* and *Lassaigne*, are still the sources from which we derive our knowledge of the chemical nature of the semen.

Vauquelin, whose analysis is the most elaborate, found in the human semen ninety parts of water, one part of soda, three of phosphate of lime and chloride of calcium, and six parts of a peculiar substance (spermatine). These statements were afterwards confirmed by *John* and *Lassaigne*. Spermatine, however, the more intimate knowledge of which would have possessed the principal interest, was no further investigated than it had been previously by Vauquelin.

Under such circumstances it appeared desirable to undertake a new chemical analysis of the semen, especially as the former researches had embraced the whole mass, without paying regard to the morphological constituents, or to the admixture of the prostatic secretion. To remove this defect, a series of researches has been instituted by *Dr. Frerichs* at our request, in the new chemical laboratory of the physiological institute of Göttingen, respecting which the following has been communicated to us for publication.

The most careful of these analyses was made on the semen of the carp, it being a fish which is perhaps best calculated for an investigation of this nature. The testicles were cut into pieces, and crushed, in order to press out the semen. Thus obtained, it presented a whitish, glutinous, or viscid mass, from which the membranous fragments were carefully removed. The residue of pure semen consisted of the spermatozoa, suspended in a fluid, and a few epithelial cells. It was perfectly neutral.

The corpuscular parts of the mass of semen were now separated from the fluid by filtration, and both were separately examined.

The *fluid* was colourless and clear, of a neutral reaction. The fluid at first filtered exhibited no coagulation when boiled, nor was it precipitated by nitric acid. Albumen, therefore, was not present. The liquid which subsequently passed through, however, on washing the mass, precipitated a small quantity of albumen on being subjected to a boiling heat, as also on being treated with nitric acid. Acetic acid, tannic acid, alum, and acetate of lead likewise precipitated albumen.

On being evaporated, the fluid left a yellowish, gum-like mass with a strong fishy smell. It re-dissolved partially in water, but was precipitated from it by tincture of galls. The insoluble residue was easily dissolved by diluted solution of potash, and precipitated by acetic acid, without being again dissolved by an excess of it.

A part of the evaporated semen was burnt: there remained an ash, consisting of chloride of sodium, as also of slight quantities of phosphates and sulphates of the alkalies.

The spermatic fluid therefore resembles a thin solution of mucus.

The *spermatozoa* which were left after

* For numerous researches on the influence of reagents on the movements of the spermatozoa, vid. Donné's Nouvelles Expériences sur les Animalcules Spermat., Paris, 1837; as well as Kræmer, p. 17. In some cases, however, our own researches have furnished a different result.

filtration were carefully washed with water: they were thus quite pure, excepting the admixture of some few epithelial cells. The subject used in the investigation had attained full generative maturity, and was almost devoid of vesicles of developement.

The spermatozoa were dissolved by cold solution of potash; a certain cloudiness which remained was due to epithelia that were slowly dissolved. The alkaline solution exhibited a copious precipitate on the addition of acetic acid; but the precipitate was insoluble in the excess of the acid, even by digestion. It was filtered off, and the acidulated fluid treated with potash, iron, and cyanic acid, but no cloudiness was produced. The substance of the spermatozoa coincides, therefore, with the "binoxyde of protein" of Mulder; it contains no albumen or fibrin.

A part of the spermatozoa were dried in a water bath, pulverised, and treated with ether. During this process they yielded a not inconsiderable quantity of fat (4·05 per cent.) of a yellowish colour and butter-like consistence. The spermatozoa, liberated from this fat, left, on being burnt, a black coal, which could not be made white by burning, and had an acid reaction, which was due to free phosphoric acid. The total quantity of fixed constituents, in which, besides the phosphoric acid, lime was recognised, amounted to 5·21 per cent.

Another portion of the expressed semen was treated with a concentrated solution of nitre. It thereby became considerably tougher, more viscid, and filtered with difficulty. On adding water, a milk-like cloudiness was produced in the filtered portion; it was, however, precipitated in the same manner as the simple watery extract by the infusion of galls. Nitric acid caused a slight precipitate of albumen.

A second series of experiments was instituted on the semen from the testicles of a cock, in which, however, the spermatozoa were only scantily developed. The contents of the seminal tubes principally consisted of cells of developement, which could only be separated with difficulty from the tissues of the testicles.

The filtered solution abounded in albumen, but contained, on the other hand, only a slight quantity of the matter (mucus), which was precipitable by acetic acid, and insoluble in excess of it.

The residue on the filter (cells of developement and spermatozoa) was dissolved in solution of potash. The solution yielded a white precipitate with acetic acid, which principally dissolved in excess of the acid (albuminous substance), whilst only a slight quantity remained undissolved (binoxyde of protein).

An old rabbit, when in the period of rutting, was subjected to a third series of experiments. The moderately turgid testicle was cut into pieces, and the milky semen expressed. It consisted of spermatozoa and numerous epithelial cells. The reaction in the testicles was neutral, in the epididymis it was slightly alkaline. It could only be filtered imperfectly. The filtered solution was cloudy, and contained many spermatozoa. The presence of a slight quantity of albumen could be perceived on the application of boiling heat.

The residue of spermatozoa left on the filter, and which were only imperfectly separated from the fluid, dissolved with tolerable ease in solution of potash, and were precipitated by acetic acid. A very slight quantity only dissolved in an excess of this acid. Only a slight cloudiness was produced in the acetic solution by ferro-cyomide of potassium.

These different experiments yield the following results: —

1. The pure semen presents the appearance of a milky fluid, of a mucous consistence, and neutral reaction. A slight alkaline reaction was perceived only once.

2. The developed spermatozoa consist of binoxyde of protein, the same substance which Mulder has proved to be the principal constituent of the epithelia, as well as of the horny tissues in general.*

3. The spermatozoa contain about 4 per cent. of a butter-like fat, as well as phosphorus in an unoxydized state, and about 5 per cent. of phosphate of lime.

4. The fluid part is a thin solution of mucus, which, in addition to the animal matter, contains chloride of sodium and small quantities of phosphate and sulphate of the alkalies.

5. The imperfectly developed spermatozoa are composed of an albuminous substance, the quantity of which diminishes in proportion to the progress of the morphological developement.

6. The perfectly developed semen contains no longer any albuminous compound.

7. The semen in fishes, birds, and mammalia possesses, essentially, the same chemical composition.

Such are the statements of *Dr. Frerichs.* The most important inference derivable from them appears to us to be the fact, that the spermatozoa, in their chemical composition, belong to the same category as the epithelial cells of the animal body. This fact removes every doubt respecting the nature of these formations, — every idea of their being independent animals. The spermatozoa are therefore (as proved both by chemical analysis and by microscopical investigation) mere elementary constituents of the male animal body, which, like their equivalents in the female animal, the ova or contents of the ovaries, are distinguished from other histological elements by their having a different physiological purpose; they have less influence on the individual in which they are produced, but are intended, when separated from that individual, to give rise to the formation of a new one.†

* Versuch einer Allgem. Physiolog. Chemie. § 532. 560.

† In spite of this functional difference we cannot help regarding spermatozoa and ova as constituents of the animal organization. Reichert, who declares them to be organizations of quite a peculiar kind,

It is probably no false inference on our part, when we express the opinion that the developed seminal elements present every where, and not merely in mammalia, birds, and fishes, the same composition. Indeed, we do not see any reason for assuming that this differs even in cases where the proper fluid is wanting, and where it is only the spermatozoa which constitute the seminal mass.

Physiological office of the semen. — Although these results of chemical analysis appear very important for the knowledge of the nature and quality of the semen, yet they afford but little assistance to an investigation respecting its *modus operandi* in the process of fecundation. Indeed, it would almost seem that an answer to such an inquiry is farther off than ever, inasmuch as we now know that a peculiar substance of a specific quality exists, which we may indeed consider as the bearer of the fructifying principle, — but that an effective *spermatine* does not exist. The truth is, " the *how*" of the fecundation is as far from our knowledge today as it was thousands of years ago; this process is still enveloped in what we feel inclined to consider " its sacred mystery." It would be different if we could prove that the spermatozoa really yielded the material foundation for the body of the embryo; that they penetrated into the ovum, and were developed into the animal (which was the assumption of *Leuwenhock*, *Andry*, *Gautier*), or else, that they become metamorphosed into the central parts of the nervous system.

However, we are now convinced that all these assumptions are without any foundation. The import of the spermatozoa must be a very different one. But this is the very point of which we know nothing with any certainty.

Leaving these views, which require no special refutation, to oblivion, the following two opinions on the nature of fecundation have taken a tolerable position in our physiology: — One of them consists in the opinion that the fructifying principle is lodged in the liquor seminis; the other, that it is centred in the spermatozoa. Both, however, agree in this, that an actual material meeting, an immediate contact of semen and ova, is indispensable to effect fecundation. The doctrine of an *Aura seminalis* has long since, and most justly, been cast aside.

It was natural that the former of these two opinions (viz. that which sought the essentials of fecundation in the fluid and its mode of action) should have found its advocates at a period when the existence of the spermatozoa was hardly known, or when, at all events, they were supposed to be mere parasitic animal forms. Indeed, this assumption is at first sight supported by arguments of a seductive nature. The liquor seminis, it was thought, comes into contact with the membranes of the ovum, and transudes them. It mixes itself with parts of the yolk, and enters with them into many chemical combinations, which fit them for a change in their capacity for organization, for the formation of cells, and for the developement of the embryo. This opinion did not, indeed, suffer at first from the recognition of the normal nature of the spermatozoa. It was indeed possible, as *Burdach* thought, to find in this very circumstance a proof of the great organizability of the semen, of the ready mode of dispersing it, which such an operation upon the ovum would *à priori* require.

Even up to the present day this hypothesis of the influence of the liquor seminis has not met with any direct refutation, although, as we shall see presently, it appears to us now, for many reasons, less admissible than it did to one of us formerly.* The presence of certain elementary structures in the seminal fluid cannot yet be connected with the part which they are intended to perform. It was indeed possible that the remarkable qualities of these structures had reference to the seminal fluid alone; that they, as it were, formed isolated, free, ciliated epithelia, and that they were intended, by means of their movement, to bring the liquor seminis into contact with the ovum; or, as Valentin supposed, that the state of mixture of the semen, so readily disturbed, was preserved in its integrity through their motions. The circumstance of meeting now and then with motionless spermatozoa is not in itself sufficient to refute this conjecture. For it might be said that in these cases such a provision might not be necessary, or that the object sought might be gained in another way, and that the spermatozoa merely existed as morphological equivalents of the moveable seminal fibres, without a similar physiological importance.

The following fact, however, appears to us of more real importance, viz. that a liquor seminis is positively not at all traceable in many, and especially not in many of the lower, animals, in worms, insects, &c.; but that, on the contrary, the whole mass of the semen is formed by the spermatozoa alone. Another reason against the former assumption is this, that an action of the liquor seminis on the ova would be impossible in many cases, — where, for instance, the fecundation takes place in the water, and without any real act of copulation, the semen being ejected from the male animals, and then left to chance whether it comes in contact with the ova or not.

Such facts speak too powerfully in favour of a specific purport of the spermatozoa in the act of impregnation to allow us to venture to say a word in support of the older assumption. In addition to this, it must be granted that the spermatozoa in the male individuals are, in a morphological point

which, in a certain degree, form a medium between animals and elementary parts of animals, seems entirely to forget that it is only the morphological condition, which can characterise a constituent of the body as such. The physiological comportment by itself ought not here to be taken into consideration at all.

* R. Wagner, Physiologie, S. 38.

of view, the representatives of the female generative products — the ova; and that, as explained in the commencement of our article, we are enabled to pronounce the presence of a particularly large quantity of liquor seminis as a fact of subordinate significance in a histological point of view.

Under these circumstances we do not hesitate any longer to coincide with *Kölliker* and *Bischoff** (the latter changed his opinion only recently) "that it is the spermatozoa which, by their contact, fructify the ovum." How this is done remains as much an enigma as the real essence, the remote cause, of every thing else that is done. We are certainly able to watch growing life in its first commencement, to fathom the laws of the successive phases of its developement; but the internal relation of all these processes is hidden from our perception.

It is possible, and, indeed, even probable, that the material constitution of the spermatozoa is somehow concerned in fecundation. Whether, however, as *Bischoff* supposes, the act of impregnation merely takes place according to the laws of the so-termed catalytic power, that a certain internal motion is transferred from the spermatozoa to the molecules of the ova, which till then were in a dormant state, we do not venture to decide. At all events, the circumstance, that it is not the spermatozoa of every animal which are capable without any distinction of fructifying every egg, is sufficient in itself to prove that we have not here to deal with such very simple relations. It is an established fact, that only animals of the same species enter voluntarily into sexual connexion, and produce prolific young ones. The importance of this law, for the preservation of once created definite forms of life, is evident.

Exceptions to this law are but rarely found, and generally are due to the interference of man. — Animals of a different species scarcely ever enter into sexual connexion in their natural state; and, indeed, this act, when it does take place under such circumstances, remains generally without any consequences. Fecundation only takes place when the respective individuals approximate towards each other in point of genus, and even then the hybrids produced are generally unfruitful. A fructifying act of procreation is known in them only in very rare cases, and that usually only when it takes place with one of the original stock, not among themselves.

This infertility or barrenness of the hybrids, coincides in a very interesting manner with an imperfect developement of the spermatozoa, a relation which we might certainly at once infer from the functional significance of these formations. In many cases there does not even seem to be any production of spermatozoa; a fact proved by the older statements of *Bonnet* and *Gleichen*, as well as by the more recent researches of *Prevost* and *Dumas* *, as well as of *Hausmann* †, with regard to the mule. One of us ‡ found the same in the hybrids of goldfinches and canary-birds. In others, real spermatozoa develop themselves; but they remain smaller than in the stock species ($\frac{1}{25}'''$—$\frac{1}{20}'''$), and without the characteristic cork-screw spirals. The thicker end is generally oblong, and frequently curved at the point, or of an irregular club form. In addition to this, the spermatozoa of the hybrids do not group together in bundles, owing perhaps to their being usually only small in number, even in the interior of the separate cysts. The microscopical examination of the semen in hybrids, the capacity of propagation of which has been confirmed, would be of importance. It is very probable that the spermatozoa in these cases have a regular developement, and their usual form.

* Müller's Archiv. 1847, S. 436.

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(*Rud. Wagner* and *Rud. Leuckart.*)

SENSATION. — (Fr. *Sensation*; Germ. *Empfindung*.) — The improved state of our knowledge of the physiology of the nervous system makes it imperative that physiologists should adopt and adhere to a precise definition of the term which forms the heading of this article.

Perhaps the simplest definition of sensation which can be given is the following; namely the perception by the mind of a change wrought in the body. According to this definition, then, sensation involves, first, a bodily change, from some cause, whether inherent or external; and, secondly, a mental change, whereby the perception of the bodily change is accomplished. A hot substance is applied to the skin sufficient to burn; a visible change is produced on the part to which the application has been made, shown by the increased redness of the cutaneous surface, and the nerves of the part are so irritated that pain must be felt if the perceiving power of

* Annal. des Sciences Nat. i. p. 182.

† Ueber der Mangel der Samenthierchen bei Hausthierchen; Hannover, 1844.

‡ R. Wagner's Physiology, § 20. Translation by Willis, § 12.

the mind be unimpaired. But unless the mind is conscious of the irritation excited we cannot say that a sensation has taken place. The person on whom the injury is inflicted may be comatose, or in a profound sleep, or under the influence of intoxicating or anæsthetic agents, and consequently his perceptive powers are in abeyance. Nevertheless, the same physical changes take place, whatever be the state of the mind, and all the physical phenomena, which may flow from or succeed to those which are capable of exciting sensation, may ensue upon them, and yet true sensation will not take place, unless the mind perceives and takes cognisance of the physical change induced.

It must then be regarded as a cardinal point in reference to the acceptation of the term Sensation in Physiology, that an action of the mind is necessarily involved, that act being of the nature of a recognition or perception of the physical changes associated with the sensation.

The true organ of sensation is the organ of the mind — the brain, and especially that part of the brain which constitutes the centre of sensation, and which extends into the spinal cord, forming the posterior horn of its grey matter. When an impression is made upon a nerve or nerves which communicate directly or indirectly with any part of this centre, a sensation is excited, provided the intracranial portion of it be in a normal state, and provided also the connection between the cranial and spinal portions be complete and uninterrupted.

Sensations depend, as to their nature, on that of the excitant, and nerves are adapted to receive impressions from various agents, ponderable or imponderable. The mechanical qualities of bodies, heat, cold, electricity, light, sound, &c., are capable of exciting their appropriate sensations, which the mind soon learns to appreciate and distinguish. Sensations thus distinguished receive the appellation of pleasurable or of painful, according as they are agreeable or the reverse. These sensations are infinitely varied in kind and in degree. It is impossible, *à priori*, to determine how a pleasurable or a painful sensation may be excited. Nor will the experience of one person be always a guide for another, inasmuch as a sensation which may be agreeable to one, may be painful or disagreeable to another.

Physiologists distinguish sensation as common and special: the former being that which is excited by ordinary mechanical or chemical stimuli; the latter is excited by special stimuli, and is exemplified in the special senses of vision, hearing, smell, taste, and touch. The nerve of vision does not, when irritated, communicate simply a feeling of pain or of pleasure; its chief effect is to excite the sensation of a flash of light. When the electric stream passes through the retina, a sensation is caused similar to that which the sudden presentation of a luminous object would produce. In like manner the mechanical or electrical stimulation of the other nerves of pure sense will create, not pain, but a feeling closely allied to that which would be excited by the application of the stimulus proper to each. This is remarkably illustrated by the effects of mechanical or electrical stimulation of the nerve of hearing and of the nerve of taste. Mechanical impulses against the tympanum occasion the sense of a dull sound, and the electric current developes a musical note. Galvanic excitation of the gustatory papillæ of the tongue causes a peculiar sour taste, and, as Dr. Baly has pointed out, the mechanical stimulation of them by a sharp tap with the fingers, occasions a taste sometimes acid, sometimes saline.

The nerves which minister to specia sensation, differ from the nerves of common sensation in no essential point of their anatomy, except in their mode of organisation at the periphery of the body. Each of them has, probably, likewise some peculiarity of connection with the brain: this is obvious as regards the olfactory and the optic nerves; less so as regards the nerves of taste, touch, and hearing. The physiological peculiarity of these nerves is then, in all probability, due to their central and peripheral organisation; and especially, perhaps, to the latter, which, doubtless, renders them peculiarly susceptible of the influence of those delicate physical agencies to which each of them is exposed.

The nerves and organs of special sensation, especially those of touch, are so comprehensive in their objects, that it would almost seem that little was left for the so-called nerves of common sensation.

These latter nerves, nevertheless, serve many important objects; they doubtless excite in the mind many feelings, agreeable or disagreeable, of pain or of pleasure, or even feelings neutral as regards pain and pleasure, which could not be developed through the nerves of special sense. The consciousness of the integrity of our limbs and of the general framework of our bodies, is secured, in a great measure, through the instrumentality of these nerves. Injuries to various parts—disturbances in their nutrition, as inflammations, ulcerations, &c. — are made known to the mind by the painful sensation excited through these nerves. The sensibility of organs and textures — *i. e.* the degree to which affections of these parts are capable of inducing corresponding affections of the mind — depends upon the number of these nerves which are distributed to them — the degree of sensibility being in proportion to the number of the nerves. Hence these nerves of common sensation exercise a conservative influence over the several textures and organs to which they are distributed, and serve to afford warning of the approach or of the existence of danger.

What some have called the muscular sense, *i. e.* the knowledge which we have of the state of our muscles, is generally attributed to these same nerves. As the sensibility of the muscles is doubtless due to these nerves, we may reasonably impute to them the faculty of informing the mind of the state and degree of contraction or relaxation of the muscles, and thus of contributing to that power of adjust-

ment which is necessary to give precision to our muscular efforts. This sense comes greatly in aid of that of touch, and of those powers which we derive from the sense of touch.

It admits of question whether this sense really requires the presence of true nerves of sensation in the muscles, and whether it may not be due to the reaction of the muscular force upon the proper muscular or motor nerves, through which, by reflection at the centre, the centre of sensation becomes affected. (See NERVOUS SYSTEM, PHYSIOLOGY OF.)

All nerves of sensation are excitors of motion under certain circumstances, but especially when they are organised at their peripheral distribution in a peculiar manner.

Objective and subjective sensations. — In the ordinary mode of exciting sensations the presence of an object is necessary. This object creates an impression on the peripheral parts of the sensitive nerves; and the change caused by this impression, being duly propagated to the centre of sensation, is perceived by the mind. Thus is produced what some metaphysicians call an *objective sensation.*

Such sensations are durable or transient, according to the force of the primary impression. The mind may continue conscious of the sensation long after the exciting object shall have been withdrawn; or the sensation having ceased, the mind may recall it, with more or less exactness, without the renewal of the original stimulus. This is one form of *subjective sensation*, in which a mental act can develope a sensation independently of any present object, but resembling a previously experienced objective sensation. Other forms of subjective sensations are caused by physical changes in nerves themselves, or in those parts of the centres in which they are implanted. These changes are caused by alterations in the quantity, but more frequently in the quality, of the blood, the deficiency in some of its staminal principles, or the presence of some abnormal element in it, or by modifications in the nutrient actions of the nerves or nervous centres. Subjective sensations of this kind are those most commonly met with. As examples of them we may refer to the motes or flashes of light occasioned by disturbed conditions of the retina, mechanically or otherwise; or of the optic nerve; or of those parts of the encephalon in which the optic nerve is implanted; tinnitus aurium, or singing in the ears, resulting from some analogous affections of the auditory nerve, or of the parts of the brain with which it is connected; pains, or feelings of tingling or creeping in the limbs (formication).

Reflex sensations. — The physical change developed in the production of an objective sensation at one part may give rise to what may be compared to a subjective sensation in another and a remote part of the body. The irritation of a calculus in the bladder will give rise to pain at the end of the penis, or to pains in the thighs. The object by which the irritation of the bladder is excited cannot exercise any direct influence on the nerves of the penis or of the thigh; through the nerves of the bladder it excites that portion of the cord in which both the vesical nerves and the nerves of the penis and of the thigh are implanted, and thus the latter nerves are stimulated at their central extremities through the influence of the peripheral stimulation; in other words, the physical changes excited in the first are reflected into the second.

Sometimes distant and apparently wholly unconnected parts may be affected in this way. Thus irritation of the ovary will cause pain under the right or left mamma; stimulation of the nipple, whether in male or female, gives rise to peculiar sensations referred to the genital organs; ice suddenly introduced into the stomach will cause intense pain in either supra-orbital nerve; acid in the stomach is apt to cause a similar pain, which may be very quickly relieved by the neutralisation of the acid. Phenomena of this kind imply some closeness of connection between the nerves of the sympathising parts in the centre, probably by means of commissural fibres connecting the respective points of implantation of the nerves with each other.

For further remarks on the subject of this article see NERVOUS SYSTEM, PHYSIOLOGY OF; and the articles on the Senses, — HEARING, SMELL, TASTE, TOUCH, VISION.

(*R. B. Todd.*)

SENSIBILITY.—(Fr. *Sensibilité;* Germ. *Empfindlichkeit*). — This term, like Sensation, should be limited to signify the power which any organ or tissue of the body has, of causing changes inherent or excited in it to be perceived and recognised by the mind. The greater this power is in any tissue or organ, the more sensitive it is, — the greater the *sensibility* of the organ or tissue; the less this power is, the less the sensibility of the organ, &c.

Sensibility, like Sensation, involves the power of affecting the mind through the body; but as the mind, of its own mere motion, may excite the centre of sensation, so, by directing the attention specially to some particular tissue or organ, it may create a sensation which, will be referred to that part, and which, by frequent repetition, may assume the nature of pain. No doubt many instances of hysterical pain are greatly aggravated by the mind being constantly directed to, and dwelling upon, the painful part.

The term Sensibility is sometimes confounded with Irritability, especially by Psychological writers. Haller has, with great precision, laid down the distinction between these two properties of tissues in the following words: —

"Irritabilem partem corporis humani dico, quæ ab externo aliquo contactu brevior fit; valde irritabilem, quæ a levi contactu, parum quæ a valente demum causa in brevitatem cietur. Sentientem partem corporis humani

appello cujus contractus animæ representatur; et in animalibus brutis, de quorum anima non perinde liquet, eas partes sentientes dico, quibus irritatis animal doloris et incommodi signa ostendit; insensilem contra partem quæ usta, scissa, puncta, ad destructionem usque cæsa, nullum doloris signum, convulsionem nullam, nullam in totius corporis situ mutationem excitat." *

The sensibility of any part must be judged of by the readiness with which changes in it are perceived by the mind. In general, highly sentient parts, when stimulated, are capable of exciting movements in the muscles of neighbouring parts; thus, stimulation of the sole of the foot excites motions in the whole lower extremity; the stimulation of any other part of the leg, whilst it might excite movements, would not produce them to the same extent. The difference is due to the greater sensibility of the sole of the foot than of any other part of the integument of the lower extremity, and also to the peculiar connection of its sentient nerves with the papillary texture of the skin.

The anatomical condition necessary for the developement of the greater or less sensibility in an organ or tissue, is the distribution in it of a greater or less number of sensitive nerves. Thus the anatomist can determine the degree to which this property is enjoyed by any tissue or organ by the amount of nervous supply which his research discloses; and physiological experiments and surgical operations furnish us with abundant evidence in confirmation of the, as it were, *à priori* suggestions of the anatomist.

The sensibility of tissues is modified by disturbances of their nutrition, and thence inflammatory affections tend to increased sensibility, and will even make parts sensitive which before were but slightly so. Thus the periosteum, which in health is but slightly sensitive, becomes, under the influence of inflammation, exquisitely sensible.

It is necessary to add that the word sensibility is also used, as applied to nerves, to signify their power of evolving the nervous force. Excitability is a better word for this purpose, and ought to be generally used, to ensure a greater exactness in the application of physiological terms than has hitherto prevailed.

(*R. B. Todd.*)

SEROUS and SYNOVIAL MEMBRANES.—(*Membranes séreuses*, Fr.; *Seröse Haüte*, *Seröse Ueberzüge*, *Wasserhaüte*, Germ. *Membranes synoviales*, Fr.; *Synovial-Kapseln*, *Synovial Haüte*, Germ.)—The names by which these structures are designated seem to have been originally derived from the appearances presented by fluids which are frequently found after death in the so-called cavities formed by their continuous interior surface.

Thus, for instance, rejecting those cases where marked symptoms of disease of these tissues precede death, the structures first named, where they offer any contents at all, present a fluid the colour and composition of which greatly approximate to that of the serum of the blood; and thence the fluid so found names the tissues yielding it as the "serous" membranes: while the interior of the joints constantly affords a small quantity of a fluid, the viscid consistence of which, resembling that of the white of an egg, gives rise to the application of the name "synovial" membrane (συν ωον) to the tissue which immediately lines the articulation, and is presumed to yield it.

But neither do these circumstances, nor that of their membranous form, by which the terms at the head of this article are completed, sufficiently express their most important characteristics. A serous membrane essentially consists of an endogenous cell-growth, covering a thin expansion of areolar tissue. The compound structure which results from this arrangement of these two tissues is thrown around the more moveable organs of the body, and also lines the cavities which they fill. By thus affording to these two opposed surfaces uniformity of texture and smoothness of surface, it greatly diminishes their mutual friction; or, in other words, facilitates their movements upon each other.

It will, I think, be advantageous to defer for the present all consideration of the possible or probable *function* of these membranes, as implying by that word an immediate organic operancy in virtue of their intimate structure; and to fix our attention chiefly on their mechanical *use* in reference to motion.

In the living man, there are many processes which necessitate changes in the relations to space of the different parts of the body. The actions of locomotion, digestion, circulation, and respiration, for instance, all imply some degree of movement in the organs which are their immediate agents, often in the more important parts to which they immediately minister; and, in many cases the protection of delicate organs appears to be partly accomplished by an increase of their mobility upon neighbouring structures. The necessity of movement thus comes to be more or less participated in by almost all the tissues, organs, and segments of the body; and assuming, what is above stated, that it is the most obvious want for which serous membranes are destined to provide, we might naturally imagine, either that these structures would pervade as universally as this requirement, or that those of similar import which should be substituted for them would sufficiently approximate in their nature and composition to be referrible to the same class of tissues: a class, in which the degrees of resemblance afforded by the different members should somewhat accord with the varying mechanical requirements of those different parts of the body, to the movements of which they were subservient.

An appeal to facts abundantly confirms

* Haller, De Partibus corp humani sentientibus et irritabilibus. — Op. Minora, t. i. p. 407.

such an inference. Observation shows that in the human body a variety of structures exist, which are united by the characteristics not only of considerable analogy of office, but also of similarity of strueture, almost complete identity of chemical composition, and intimacy of pathological relations.

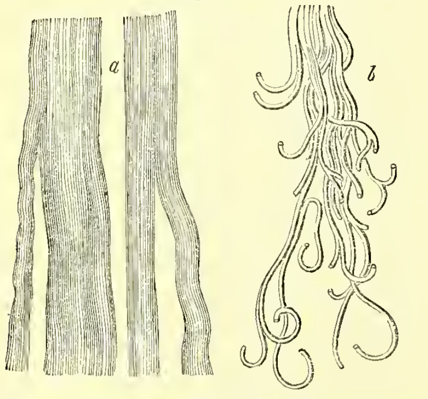
Adopting the possession of these common properties as a natural and safe basis of classification, we form a group in which are included all those tissues which serve to limit, define, or facilitate movement. The class of structures thus constituted was formerly termed " the Cellular System ; " but the cellularity which the name connotes, as it was never supposed to be predicable of all its members, so it is now known to be erroneously used of that part of them to which it was originally applied ; and they have therefore been preferably arranged under the head of " Passive Organs of Locomotion." And if any should consider this term open to the lesser objection of specifying a general, but not essential fact, that of " Passive Organs of Movement " might be again substituted.

On this view we may regard serous membranes as forming one of a group of tissues. A further analysis of this group shows it to be composed of several members, separated from each other by differences, in which we may recognise a progressive, though somewhat interrupted, series of gradations. These differences we shall now proceed rapidly to trace.

Two important microscopieal elements pervade all these struetures, and will therefore demand some attention. These are *the white and yellow fibrous tissues.*

The *white fibrous tissue* (*fig.* 395. *a*) consists of bands or bundles of a very variable width, which, unless artificially stretehed, take a sinuous or wavy course ; and, at distant intervals, include cell-nuclei in their substance. They are marked with striæ, which take the direction of their length, and, by their mutual proximity, give a fibrous or fibrillated appearance to the whole mass. But these markings are not exactly parallel to the borders of the band; and since the tissue, though easily divided longitudinally to almost any degree of minuteness, eannot be split up into uniform and definite fibrils of a diameter corresponding with the transverse width which intervenes betwcen one of these striæ and another; and since it is also swelled up into one shapeless and semitransparent mass by the action of acetic acid ; it seems highly probable that they are limited to the surface of the bundle, or its immediate neighbourhood. At any rate, they do not sufficiently divide the mass to give it a filamentous constitution, or to render it " fibrous " in the true sense of the word.

Fig. 395.



a, White fibrous tissue; *b*, Yellow fibrous tissue. *After Todd and Bowman. Magnified* 320 *diameters.)*

The *yellow fibrous tissue* (*fig.* 395. *b*) is contrasted with the preceding form, not only by its colour, but equally by its minute structure and properties. It consists of separate fibres, the size of which varies considerably in different parts, and, in a lesser degree, in any one specimen. They are exceedingly disposed to curl up, often assuming almost a spiral form ; and are rendered very distinctly visible by the dark margin which their great refracting power gives them. Their branchings are generally dichotomous, and the processes thus given off are of a size which nearly equals that of the original stem ; and they may often be traeed to their union with neighbouring ones, so as to form a kind of trellis-work.

The first form exists alone in tendons, ligaments, and the stronger fasciæ latæ ; its inextensibility and strength admirably adapting it to the use of mere passive resistance to an external force. The second is highly elastic, whence it is often termed " the elastic tissue :" it is chiefly found where, along with a certain amount of yielding, is also required a complete restoration of the previous state without any further expenditure of muscular force, the long duration of an aetion often rendering it advantageous to avoid the fatigue which the eonstant exereise of volition and muscle would imply. And as these conditions are much rarer than the simply mechanical wants which the preceding form is destined to supply, so also is the tissue which fulfils them, being found separately in but a few parts of the body; viz. in the ligamenta subflava, and in certain portions of the vocal and respiratory apparatus. Here it is in sparing quantity ; but in the vast ligamentum nuchæ, which suspends the ponderous heads of the horned graminivora, the uses of the tissue are exemplified in a very striking manner.

Chemically, they are distinguished by the white fibrous tissue containing much gelatine, or rather *yielding* it by boiling ; while, from the yellow, none can be obtained. They are both little disposed to putrefaction, and retain their peculiar physical properties almost unimpaired by time.*

* In an Egyptian mummy, I lately found these tissues (after moistening) displaying as perfect a structure as a specimen of yesterday could have done.

A mixture of these two elements constitutes *the areolar tissue*, which enters so largely into the formation of almost all the organs. The bands of the one and the fibres of the other are closely interwoven, although without mutual continuity; each giving off branches which again unite with the other neighbouring subdivisions of the same kind, so as to form a complicated interlacement of the two networks. This arrangement results in an innumerable series of meshes, which everywhere communicate with those in their immediate proximity, and the size and shape of which varies within very wide limits. And these limits are frequently still further extended, since the separation of some of these microscopic meshes, and the approximation and condensation of others, gives rise to the formation of a secondary net-work, which is visible to the naked eye, and which, though still open in every direction, possesses, especially in inflated and dried preparations, an appearance sufficiently resembling that of cells to remind one of the name formerly applied to this structure, which was called, as if κατ' ἐξοχήν, "the cellular tissue."

The *proportion* in which these two constituents are mixed varies greatly in the areolar tissue of different parts of the body; the preponderance of one over the other following that of the conditions which were previously stated to regulate their separate presence. Thus, the likelihood of its frequent and great distention is often a requisition of increased elasticity, and is then accompanied by an increased proportion of the yellow element.

Similarly, the *amount* of this compound structure present in different parts appears to depend mainly on its uses.

Its offices of uniting the different textures, and of convoying the vessels and nerves, render it necessary that more or less of the tissue should always be present on the exterior of an organ; and the same circumstances would lead us to expect a slight penetration of its surface.

In the interior of organs, however, its absence is by no means infrequent, and is very significant of its use. Thus, the minute elements of the osseous tissue are physically insusceptible of movement; the permissive and facilitating structure becomes unnecessary and impossible; and is therefore absent. The highly delicate nervous pulp not only possesses no inherent mobility, but, by the extreme delicacy of its structure, offers a physiological obstacle to movement of equal importance with the preceding, and is accompanied by a similar absence of the tissue. The intimate mutual connection of the muscular fibres of the heart, and their association in a common and nearly simultaneous movement, is associated with a like deprivation of this interstitial structure. The same absence at once of the necessity and of the tissue is seen in glandular organs, the situation of which shields them from injurious external force, as appears to be the case with the liver.

But where opposite circumstances obtain, where extent and variety of movement imply considerable mobility of the neighbouring muscles of a limb, or situation exposes an organ to external violence, a large quantity envelopes these different textures, penetrating between the different muscles and isolating their several fibres, or breaking up the gland into numerous subdivisions, moveable on each other: of this latter, the mamma is a familiar instance.

A similar relation might be traced in the wider circumstances of its application. Not only does it form a web of union to the whole body, but it also presents a special layer of considerable thickness, which invests its surface, and partitions which isolate its muscles. And something of a corresponding minimum is found in those animals whose locomotive movements are few and simple, or whose situation and habits little expose them to external violence. So that a rough gradation might be traced through fishes, cetaceans, and reptiles, to mammals; in which last class man stands pre-eminent in the number and complexity of his voluntary motions, and in the remarkable amount of this subservient tissue.

An increase in the freedom of movement of contiguous parts is associated with an increased laxity of this web, the meshes of which become both longer and wider, so as to be more capable of stretching. They thus allow a greater amount of separation to take place between the parts which are attached to the extremities of their irregular net-work.

Bursæ. — Here and there throughout the body, where integument or tendon glides over a bony prominence, a further provision occurs, as the development of distinct cavities, which are lined by a smooth shining surface. By dissecting their parietes from the surrounding looser cellular tissue, they may be artificially exhibited as a membrane; and hence these sacs, closed at all points of their circumference, have received the appellation of *bursæ*. In the majority of instances, their interior is almost void of contents; but, in exceptional cases, they contain a considerable quantity of a glairy, mucus-like fluid, which closely resembles that before alluded to, as naming, from its consistence, the *synovial* membranes. This similarity of their contents was till lately supposed to be the only analogy borne by these structures to the synovial membranes of the articulations; and hence they have been included by Henle* and other systematic writers in a class of "Pseudo-serous membranes," and characterised as lacking an epithelium on their inner surface.

Reichert†, however, detected a layer of nucleated cells lining their interior. He stripped off a fine layer from this surface under water, and, upon expanding and compressing it, found that it was covered by numerous darkish nuclei, of somewhat elongated shape, and upon which acetic acid

* Allgemeine Anatomie, S. 364.

† Müller's Archiv., 1843. Jahresbericht für Mikroscopisch Anatomie, S. 339.

exerted its ordinary effect; defining their outline, and deepening their colour. But although the existence of a stratum of nuclei was sufficiently distinct, the contour of the cells themselves he does not seem to have determined.

The resemblance of these bursæ to the membranes which form the especial subject of this article is thus rendered so complete as to deserve a brief notice of their structure in this place ; and the more so, perhaps, that the writer is enabled to add a few details which place this similarity in a still more striking light.

The *subcutaneous bursæ* are the simplest form of these structures, and are very numerous in the human subject, but seem much less frequent in other animals.

The *areolar tissue* which immediately invests these sacs is, for the most part, very lax, and contains an unusual quantity of the yellow fibrous element, the fibres of which are here of large size.

On removing this from the outer surface of the bursa, it is seen to be composed of a more compact and whiter tissue, which is tough and much less extensible than the looser texture which surrounds it. The microscope shows this to consist of the white and yellow fibrous tissues. The latter is generally in much less considerable proportion than in the ordinary areolar tissue, while at the same time its constituent fibres are of a smaller size : they possess their ordinary arrangement, and branch and unite sparingly with each other.

The white fibrous element is disposed in wavy bands of varying size. These take a course parallel with the surface of the bursa, and, apparently, with few interstices or reticulations ; thus forming a dense laminated structure, which cannot be broken up without much difficulty. In this structure, at a little distance from the interior, are arranged the blood-vessels, the capillary meshes of which are of tolerably large size, and generally take a more or less quadrangular shape. It is by no means unusual to find one, two, or more fat cells lying comparatively isolated in this mass of tissue, with a loop or curve of capillary thrown around them in the ordinary manner. Of the nerves of these membranes I am not qualified to speak. As the white fibrous tissue approaches the internal or free surface which limits the cavity, the bands appear somewhat to differ from this description, and become more refractile, acquiring a yellowish colour, and seeming more solid.

The interior of the bursa forms a cavity which is very rarely a solitary and regular one, being almost always complicated by the possession of membranes and threads, which run across its interior, and thus shut off incomplete secondary cavities. The number and situation of these is quite irregular in different subjects ; and, of the two complications, the first is the most common, giving rise to the production of folds, which project into the general cavity in a manner which may be compared to those processes of dura mater, which form the tentorium and falx cerebri. The surface itself is hard and smooth, and the blade of a knife removes little or nothing from it by scraping with any ordinary force.

It deserves to be stated that in examining different specimens differences are seen, both in the amount of the yellow or elastic tissue, and in the degree of condensation of the white element, which ought to be called considerable, *i.e.* that they seem to range, from tough, inextensible, white sacs, of comparatively simple form and composed of little but white fibrous tissue, to a highly elastic membrane, containing a tolerable quantity of the yellow fibrous tissue, and a cavity much complicated by numerous threads and processes. How far these diversities are associated with differences of age or habit, it is impossible to state.

The whole of this internal surface is covered by a cell-growth, but the exact shape and arrangement of the constituent particles are rendered difficult of observation by one or two physical peculiarities not devoid of interest. On examining the free aspect of a thin horizontal section, made just below the surface, the dark mass of fibrous tissue upon which the cells are placed, obscured and intersected by the numerous lines which mark its fibres, very seldom allows more than a layer of nuclei to be observed. And the application of acetic acid, which swells up this tissue, and renders it transparent, at the same time dissolves the cell-wall, and leaves the dark nucleus alone occupying its place. On the other hand, scraping the surface, instead of obtaining a layer of cells, mutually adherent by the adapted sides of their polygonal margin, and easily separated from the subjacent tissue, as is the case with the serous membranes, — instead of this, little or nothing is stripped off, save a few scattered cells with much débris and many oil-globules. If greater violence be used, a portion of the subjacent structure is torn off, and offers the same optical difficulties as the thin section alluded to.

The careful and repeated examination of different portions and fragments, both with and without the application of dilute acetic acid, leads to the following results.

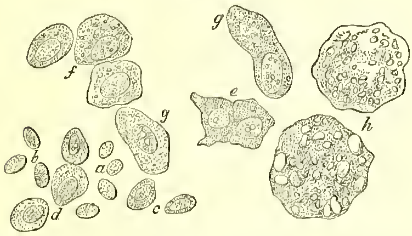
I have been unable to verify the existence of a *basement membrane*, although, on analogical grounds, it might perhaps have been expected that such a structure was present. On getting a favourable view of a vertical section, the surface immediately beneath the epithelium appears to be smooth and defined ; but there is nothing which resembles the other surface of a membrane intervening between the cell-growth and the fibrous tissue. The latter appears to be immediately subjacent to the cells, and is continued outwards without any interruption to the surrounding areolar tissue, in which course it is subject to the modifications already described.

In one instance only many elongated nuclei were observed, which were of extreme delicacy, and were seated upon or in a mem-

brane of little more than their own breadth ; this membrane was prolonged at their opposite poles into ribbon-shaped processes, of excessive tenuity and considerable length. Such a description greatly approximates to that given by Mr. Goodsir*, of the torn-up "germinal membrane" of the serous tissues; but I have not studied these objects sufficiently to be able to affirm or deny the complete applicability of his description to them. In the instance where I saw it, I rather inclined to consider it a distortion and elongation of the ordinary epithelia, due to accidental mechanical violence, inflicted during the examination of the specimen.

The characters of the cells. — The different individual cells which may be found floating in the field of the microscope exhibit great diversities of appearance, so as to offer almost every gradation of cell-growth. The first form visible (*fig.* 396. *a*) is that of a delicate pale, flat, cytoblast, which is either unaffected by the application of acetic acid, or is even rendered somewhat more transparent by it. The next gradation (*b*) is still a cytoblast, *i.e.* uncomplicated by the addition of an outer cell-wall ; but dilute acetic acid renders it yellowish, and much more distinct. In the next variety (the next stage of development, I think it may safely be termed), two outlines

Fig. 396.



Epithelium of the Subcutaneous Bursæ. (*Magnified* 320 *diameters.*)

are visible (*c*), one of the nucleus or cytoblast, another of a cell-wall exterior to this; and the distance between the two gradually increases in different individuals by an increase in the size of the cell, which, however, retains its flattened oval shape. Its contents are either transparent, or very faintly granular : and the succeeding modification mainly consists in the increased granularity of the contents of the cell, and in the assumption of a more or less polygonal outline. This is seen in the figures marked *d*, *e*, *f*, *g* ; and these diagrams also illustrate another detail, viz. that the polygon is anything but a regular one, offering a variety of forms, some of which approximate to a triangle, others to a trapezium or a pentagon. And though sometimes (as in those marked *c*), they may be seen apposed in groups of two or even three, yet it will be recollected that many of these forms are physically insusceptible of the neat tesselated adaptation which is seen in the hexagonal cells of serous membrane. The wall of the cell is still soluble in acetic acid, and the outline of the nucleus is darkened by its application as usual. The subsequent alterations consist in a gradually increasing flattening and widening, both of the cell and nucleus, but especially of the former, which finally more than doubles the diameter of the polygonal cell, and at the same time reduces its depth to a mere scale. The granular or mottled appearance of the contents before spoken of now reaches its maximum, often forming yellow refractile dots or beads, which appear to be incompletely fluid (*h*). The nucleus, during this process of flattening, becomes somewhat larger, and much less distinct; and in the larger and more mottled scales, it completely disappears, an effect which might at first be supposed due to the obscuring of its outline by the granular contents, but which is evidently independent of this cause. A further difference is presented by the action of acetic acid, which fails to affect these broad squamous epithelia in any perceptible degree.

The arrangement of the cells. — Hitherto we have merely enumerated and distinguished the different forms of cell-growth which may be detected after tearing up casual portions of the tissues lining the cavity : we have next to determine the relative quantities of the different varieties, and to specify their arrangement, both with respect to each other and to the surface which they clothe.

The forms which appear greatly to predominate in quantity, are those represented in the figure as *c*, *d*, *f*. Some of these are nucleated cells of a flattened oval shape, and others are probably similar cells, in a stage immediately subsequent to the preceding, when the oval vesicle becomes more or less angular by the lateral pressure of its neighbours opposing its own inherent expansion ; or, regarding a number of such bodies, when a simultaneous expansion obliges their yielding walls to adopt that shape which presents the fewest interstices, and thus allows of the greatest amount of mean area. Were the process conducted with mathematical accuracy, this shape would obviously be a hexagon, and in the serous membranes it will be seen with how few exceptions the cells approximate to that form ; but in the outline of these bursal epithelia, as has been already seen, the oval or circle glides into the polygon by many gradations.

Generally speaking, there is but one layer of cells, and these are usually more or less polygonal ; but not unfrequently a few oval ones are seen in close proximity to each other, and only distinguishable by the smaller distance between their nuclei, and the occasional overlapping of their curved borders.

The chief exceptions to the unity of the layer are twofold, one at each extremity of the cell-life, so to speak. For instance, pale flat cytoblasts (*a*), in sparing quantity, sometimes underlie the stratum ; while, on the other hand, it is often covered by the very large polygonal squames (*h*). In either case,

* Anatomical and Pathological Observations, p. 41.

it is almost impossible to observe both these different layers *in situ*, from the transparency and flatness of the objects just named causing them to be effectually shrouded and lost in the outline of the granular polygonal layer; but, from various reasons, I have little doubt that the preceding description may be regarded as tolerably correct. It is especially countenanced by these facts, that in looking directly upon the free surface, I have never seen cells referrible to either of the two extremes, but always such as from their shape, their size, and the mutual distances of their nuclei, would be included in the varieties (*c*, *d*, *f*) ; while, nevertheless, a careful tearing up of the same specimen often afforded the cytoblasts and scales. The latter were in much greater quantity than the former, but whether they existed over the whole surface of the bursa, or on particular parts only, I am unprepared to state. And whether the cytoblasts chiefly underlie the oval or the polygonal forms, is a question equally impossible to answer satisfactorily, yet by no means so insignificant an inquiry as it may seem at first sight. On the whole, their usual appearance in conjunction with the younger forms, and their comparative absence from the polygonal-celled serous membranes, somewhat tend to associate them more with the oval than with the polygonal epithelia.

The subtendinous bursæ. — It frequently happens that, where tendons in passing to their insertion lie upon a bone, the action of the muscle with which they are continuous gives rise to considerable friction of the two surfaces against each other: and, in some cases, the projecting surface of the bone is even made the pulley by means of which the direction of the muscle's action is altered, through a similar change in the course of the tendon; a condition which necessarily implies a yet greater amount of resistance and friction. In these circumstances, bursæ are found interposed between the osseous and tendinous surfaces. These bursæ have* hitherto been regarded as in all respects similar to the subcutaneous sacs just described, and the possession of an epithelial lining has been denied them equally with these. But while they apparently present the same form, that of a shut sac, continuous with itself in every part, and are, in the majority of instances, indistinguishable from them by the naked eye, they are yet separated from them by important differences. They present, it is true, a cell-growth analogous to that described in the preceding structures; but they differ from these in the extent of surfac eon which that growth obtains, in the nature of the tissues which are substituted where it is absent, and, in a lesser degree, in the general characters of the membrane where it is present: the general effect of these differences being greatly to liken the anatomy of these structures to that of the joints.

On laying open one of the least complicated of these bursæ, such as they are generally seen in the dog and cat, we gain entrance to a simple cavity, which everywhere possesses a smooth and shining interior. Above is the tendon, below the periosteum of the bone ; on either side, a delicate continuous membrane separates it from the neighbouring areolar tissue. It might be expected that this membrane covered the neighbouring opposed surfaces of tendon and periosteum ; and, indeed, the description usually given by authors affirms the existence of such a covering, to which it attributes the smoothness of their surfaces. But this is not the case : a careful examination of these structures with the microscope distinctly shows that their surfaces of friction are quite devoid of this membrane, and have assumed more or less of the structure of cartilage.

The *membrane*, then, may be described as preserving the continuity of the inner surface of the bursæ in the interval between the two rubbing surfaces. It is attached to the tendon and periosteum by a mingling of its areolar tissue with these structures. Like its neighbouring areolar tissue, it is extremely elastic and delicate ; so that its tenuity often equals that of the serous membranes. It is plentifully supplied with blood-vessels; and, generally, there is a considerable amount ot adipose tissue on its attached surface, the capillaries of which are arranged in the same manner as those in the bursæ previously mentioned, or those which supply the fat cells of the so-called " Haversian glands " in the joints : — viz. the same capillary plexus, which immediately underlies the epithelium, gives off occasional loops to surround the adipose vesicles. The *epithelium* itself resembles that of the subcutaneous bursæ in the intimacy of its adhesion to the subjacent tissue, as well as in the comparatively slight connection which subsists between the cells themselves: but it appears to differ from it in the greater quantity of the oval cells and cytoblasts, of the former especially : and in the immediate neighbourhood of the fat vesicles this shape seems to predominate to the comparative exclusion of polygonal forms.

In the human subject, the surface of bone on which the tendon plays often presents a covering of what has all the appearances of fibrous tissue mingled with cartilage, or " fibro-cartilage ;" and even in smaller animals (as the cat), in whom the tissue offers no visible difference from the neighbouring periosteum, its intimate structure exhibits a similar transition. The bursa beneath the tendon of the obturator internus, where this turns over the border of the ischium in its pro-

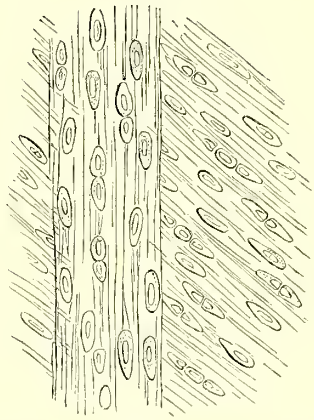
* Since writing the above, I have been informed that a description of these structures, somewhat resembling that given by the writer, has appeared in a provincial German periodical of a few months' earlier date. I have been unable to meet with it however. So also, the account which I have given of Synovial Membranes must not be understood as claiming any priority. I believe that priority (and probably something more) belongs to Mr. Rainey; a report of whose paper has appeared in the " Proceedings of the Royal Society," a publication which I have found difficult of access.

gress towards the trochanter of the femur, is a convenient one for examination. On making a thin section parallel to the osseous surface, it is found that the bands of the white fibrous element which constitute the periosteum are considerably changed where they line the bursæ. They are much less wavy than usual, and, at the same time, have become much more brittle and transparent. Besides becoming more linear, the markings have altered in another respect, viz. they are much less frequent, and are placed at more regular distances. The ordinary epithelium which elsewhere lines the cavity has disappeared, and, in its stead, we recognise a great number of cells irregularly scattered over the surface of the specimen; although even now one may perhaps trace an approach to a longitudinal arrangement in their greater proximity in this direction. These cells, in respect of their solidity, their somewhat angular shape, their colourless transparency, and refractility, greatly resemble those seen in articular cartilage. They are, in fact, *cartilage corpuscles*. But although exactly on the surface these cells are somewhat flattened, and scattered with comparative irregularity, this appearance by no means extends any depth in the tissue. A slight alteration of the focus shows that, immediately beneath the surface, corpuscles are not only less numerous, but also assume a distinctly linear arrangement; and form somewhat interrupted longitudinal rows, which chiefly occupy the interstices of the altered bands of white fibrous tissue. The corpuscles themselves are here more angular and elongated. By further altering the focus, and obtaining a deeper view, the lines marking these surfaces are seen to be crossed by others; and a closer inspection reveals the existence of two strata: one, the superficial layer just examined, of which the lines are in the direction of motion, or transverse to this border of the ischium; and another deeper layer, which lies at right angles to the preceding, and immediately covers the bone. In the latter, the same corpuscles exist, but in rather fewer numbers. The application of acetic acid slowly swells and dissolves the intercellular substance, and renders the cells more distinct, but does not deepen their colour. After a considerable interval of time, it attacks the corpuscles themselves, and renders them invisible; apparently more from its effect on their relations to the refractility of the surrounding substance, than from a real solution.

In like manner, the under surface of the tendon offers a similar cellular structure, and a corresponding, but much less considerable, modification of the fibrous tissue itself. But this change, which, on the surface, is so well marked, gradually diminishes as one examines successive and deeper horizontal sections; and, finally, at a certain depth, the intercellular substance altogether loses its cartilaginous characters, the cells themselves vanish, and the tendon completely resumes its ordinary structure.

The crossing of two strata at right angles to each other, which is witnessed in the modified periosteum, is a frequent anatomical peculiarity of the original tissue, and not essential to the modification. And something very similar is seen in the tendon. The tendinous bundles to which the several muscular fibres are attached, are successively received into the border of the oblique tendon; and very frequently, in joining it, a certain proportion of their fibres swerve aside from its track, scatter themselves, and strengthen the cord as a whole, by crossing its surface at a varying angle, and forming a thin stratum superficial to it. Where the tendon assumes the peculiarities just alluded to, the markings and corpuscles of this superficial layer are seen decussating those of the larger and deeper mass which take the direction of the tendon. This crossing of two strata is indicated in *fig.* 397.

Fig. 397.



Under or Bursal Surface of Obturator Internus Tendon. From the Cat.

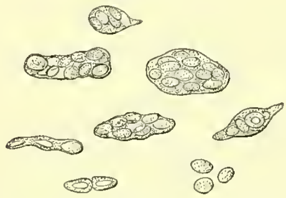
a, superficial stratum; *b*, deeper layer lying at an oblique angle to the preceding. (*Magnified about* 180 *diameters.*)

The chief differences between the cells on the surface and those at a greater depth have been already indicated; viz., that the former are more numerous, flatter, and more oval. But the shapes and appearances of the deeper layer deserve further consideration, since they present the phenomena of a fissiparous genesis of cells, which the upper stratum does not; so that it is perhaps difficult to avoid attributing the increase of numbers and alteration of shape which is seen near the surface to the gradual advance of the multiplied corpuscles in that direction. The stages of the process are the same as may be observed in other tissues. An elongation of the nucleus is followed by an hour-glass constriction of its middle; a dark line across the corpuscle then testifies to the fission of both cell and nucleus; and, finally, the two new cells separate, and their walls surround the nucleus at a more equal distance in every part. Most of these steps may be observed in *fig.* 397.

The conjecture just mentioned derives considerable support from a comparison of their structure in the adult with their younger and fœtal conditions in the same animal. In the latter especially, the quantity of cell-growth on the surface is so great, as, in respect of mere continuousness, almost to merit the appellation of an epithelium. But though its constituent cells lack the angularity, and somewhat the size, of those which belong to the inferior strata ; yet, like the same cells in the adult, they are quite distinguishable from the epithelial covering of the bursa, not only by their appearances with and without acetic acid, but by the distance to which the shifting focus follows them. At successive depths, they are seen to become somewhat larger, more angular, and wider apart ; and the same process of fissiparous multiplication may be detected in them as in the adult cells. We shall see that these differences at the different stages of the animal's life experience a close parallel in articular cartilage.

In a few instances, I have witnessed another form of cell-multiplication in this tissue. It occurred in one or two cats of a few months' age, but I cannot say whether it is limited to any particular period of their life. It is represented in *fig.* 398, and con-

Fig. 398.



Compound Cells of Bursal Fibro-cartilage. From the young Cat. (*Magnified* 400 *diameters.*)

sists of an oval or elongated vesicle or cell of limitary membrane, which is filled with, and usually more or less bulged by, a number of cytoblasts. These compound vesicles were sparingly scattered through the cartilage-like tendon and periosteum ; similar masses of cytoblasts, of a spherical form, may occasionally be seen in young articular cartilage ; and, indeed, instances of this form of cell-multiplication might be adduced from many structures, temporary, permanent, and morbid, but their introduction would be foreign to the province of this article.

The constitution of the *synovial sheaths* of tendons resembles that of these bursæ in many respects ; and, on the whole, offers a still closer approximation to the structure of a joint. In many places, the sheath consists only of a delicate transparent membrane, the tenuity of which approaches that of the serous membranes, and which, like them, rests on a stratum of loose areolar tissue, and is reflected from the parietes of the cavity to the tendon where it enters it. Here they possess an oval or slightly angular epithelium, which constitutes only one layer. But almost every such tendon, in some part or other of its course, offers an alteration of direction implying considerable friction, and effected either by a projection of bone, or by a pulley of thick and strong fascia. Such are the grooves and posterior carpal ligament for the extensors at the back of the wrist. And here is again discovered the condition which was previously stated of the obturator tendon, but with some slight modifications ; firstly, that the approximation to the structure of cartilage, here visible to the naked eye, affects equally the whole periphery of the tendon, instead of being limited, as heretofore, to one of its surfaces ; and, secondly, that the cell-growth is more plenteous, sufficiently so as to offer scarcely a point of the surface unoccupied by cells ; of which the shape, size, and disposition almost exactly resemble those of the surface of articular cartilage in the young mammal or the adult reptile.

In the cartilaginous-looking portions of the sheath, a similar, but less extensive depth of cell-growth obtains ; and I believe I have recognised the same condition in the surface of the crucial ligaments of the knee-joint.

The *vessels* of these synovial sheaths are very numerous, and their capillaries exhibit a tortuous arrangement which is identical with that witnessed in the articular synovial membranes hereafter to be described. But this copious supply of vessels is limited to the delicate membranous portions of the sheath, and to those mesentery-like reflections which here and there pass from the parietes to the contained tendon. Wherever the tendons are subject to much friction, and evince the partially cartilaginous structure already described, there the vessels are absent from those superficial and cell-containing strata, and, so far as I know, are limited to the deeper and non-cellular parts of the tendon.

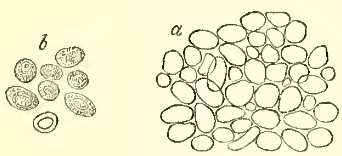
Synovial Membranes. — The synovial membranes are structures exceedingly analogous to the preceding, and consist of a layer of cell-growth, which covers the inner surface of the ligaments that connect the different segments of the skeleton in the diarthrodial joints, and which thus partially lines the " cavity " or interior of these articulations.

They have been usually described as resembling the *bursæ mucosæ* both in the nature and consistence of their secretion, and in their constant adherence to the morphological character of a shut sac ; while the absence of epithelium predicated of these bursæ, has been laid down as the chief anatomical distinction between the two structures. And, on the other hand, they have been likened to the *serous membranes* by the common possession of a tesselated epithelium, and by their continuity over the whole surface of the cavity and its contents ; while they have been severed from them by the difference in the composition and consistence of their secretion, — a viscid alkaline fluid, instead of a more limpid and neutral one. Most of these statements can only be received with some modification.

In the following sketch, such details as are more or less common to the synovial membranes in general will chiefly be treated of. For a description of their more salient peculiarities in the different joints, the reader is referred to the articles headed with the names of the several articulations.

The *epithelium* of these structures presents characters which afford some grounds for distinguishing it both from that of the bursal and serous membranes. It forms, for the most part, but one layer, the forms of the constituent cells of which vary to the same extent as those witnessed in the bursæ. But the broad, squamous, polygonal epithelia are comparatively rare; and in by far the larger extent of its surface, the predominant shape is that of a slightly flattened spheroidal, or oval, or somewhat angular cell, such as the majority of those represented in *fig*. 399, in

Fig. 399.



Epithelium of Synovial Membranes.
a, free surface seen in sitû; *b*, separated cells. (*Magnified* 200 *diameters.*)

some of which are seen decussations of two convex outlines, caused by the margin of one cell slightly overlapping that of its neighbour. Acetic acid exerts an unusual effect upon the cell-membrane, swelling up its outline very much before dissolving or rupturing it; an appearance which obtains in the more flattened and polygonal epithelia of the serous membranes, but, so far as I have seen, in a much smaller degree. Like those of the bursæ, they are firmly attached to the subjacent tissue, and possess little mutual adhesion; though here and there a cluster of two or three more polygonal than usual may be found. Cytoblasts are rare, the cells appearing to be completed by the addition of the outer membrane when yet extremely small, (*fig*. 399. *b*.)

All these peculiarities might perhaps be generalized in the statement, that the cells which cover the general surface of these membranes are in a younger and more active stage of cell-life than those of the bursæ. And a slight yet perceptible difference in the same respect has been already indicated as existing between the subcutaneous and subtendinous members of this class of structures. Immediately beneath these cells lies a stratum of looser *areolar tissue*, which connects the membrane with the inner aspect of the ligaments of the joint. It includes little of the yellow fibrous tissue, and its meshes are comparatively few and close: exteriorly, they unite, by a gradation of structure, with the dense white fibrous tissue of which the ligaments are composed.

The vessels of the membrane are exceedingly numerous, and its capillaries form a horizontal plexus, which ramifies immediately beneath the epithelium in the areolar tissue just mentioned. The great vascularity of the tissue has long been known, but the capillaries are not only very numerous, but offer a much more remarkable peculiarity.* They are greatly increased in their length, so as to be everywhere extremely tortuous, and sometimes this tortuosity almost amounts to a spiral disposition. On looking at the broad surface of well-injected specimens, an exaggeration of this disposition here and there, gives rise to small patches of tortuous capillaries; but the arrangement is clearly a general one, and extends, in some degree, to every individual capillary of the net-work. But though the length of these vessels in a given space is thus greatly augmented, the frequency of their

Fig. 400.

Capillaries of the Synovial Membrane, projecting by their convex border over the articular cartilage. From the human finger.
a, artery; *v*, vein. (*Magnified* 40 *diameters.*)

inosculations does not seem to experience a corresponding increase. Their tortuous form is represented in *fig*. 400.

The preceding description of the vascular, fibrous, and areolar constituents of synovial membrane applies only to the simplest form of that tissue, which consists of a plain flat expanse of membrane. In special joints, as well as in special parts of every joint, each of them experiences modifications deserving of notice. Over the cartilage of the articulation, for instance, all of these cease; and deferring for the present a consideration of the analogous structure which here supplies the place of epithelium, we come to consider the anatomy of the synovial membrane where it reaches the border of articular cartilage.

The fibrous tissue exterior to the mem-

* I have here to express great obligations to Mr. Quekett, of the Royal College of Surgeons, since his kindness supplied me both with specimens, and with many further details of this arrangement, till then unknown to me. The joint from which *fig*. 400. was sketched, was taken from a hand admirably injected by him.

brane, and with which its areolar tissue is mingled, passes to the side of the articular cartilage, and immediately becomes inextricably interlaced with its fibrous tissue or perichondrium. The plexus of capillaries, somewhat more tortuous here than on the plain surface, runs up to the edge of the cartilage, or may even advance a very short distance over it, where it is not exposed to friction during the movements of the joint. Its various branches then suddenly stop short, and each taking a looped course, returns upon itself in the same tortuous manner. This distribution is represented in *fig.* 400.

The layer of epithelium offers equally remarkable appearances; a few of its particles are very slightly flattened, but most of them are spherical, and of very various sizes, of which some are extremely large. All of the larger contain a pale and rather flattened nucleus, which is in contact with a part of their inner surface. The cells are also of singular delicacy and transparency, and are, to all appearance, distended with a fluid, the refractility and colour of which closely approximate to that of water. The areolar tissue which forms the foundation of the membrane being diverted at this point to join with the ligaments and perichondrium, the vessels are left comparatively naked; and so far as I have been able to make out, upon these bare capillaries the cells are seated, without the intervention of any membrane. They thus form what is indeed a covering for the vessels (since there is no part of them upon which large or small cells or cytoblasts are not placed); but, as is evident from their shape only, they constitute a layer in a very different sense from those in which the epithelium of the serous membranes does so.

In some of the more complex joints, another modification occurs, which is in many respects very similar to this, viz. distinct folds or involutions of synovial membrane, which project into the cavity of the joint. The best instances of this are seen in the knee-joint, where they form what are called the "mucous" and "alar ligaments." The folds which constitute these come off horizontally from the synovial membrane in the front of the articulation, but with a considerable interval between their upper and lower layers, which is filled with adipose tissue. They contain besides, a plexus of vessels, of which some, lying immediately beneath the membrane, ramify in the flexuous manner described; while the deeper are distributed to the fat vesicles, throwing loops around each in the manner peculiar to this tissue. A very small quantity of fine areolar tissue is present, chiefly as a covering and protection to the vessels. Gradually going backwards, they lose their adipose tissue, and taper to an edge, which accurately fits into the interstice between the condyles of the femur and head of the tibia. Here the upper and under layers come into contact, and in the middle line pursue their way backwards as the ligamentum mucosum, a flat, thin duplication of the membrane; until, finally, at the anterior termination of the notch between the condyles, they terminate by joining the synovial covering and fibres of the neighbouring crucial ligament. On either side of the middle line, the process of synovial membrane terminates, by a convex margin, a little beyond the point where it ceases to contain fat: these are the "alar ligaments."

On the ligamentum mucosum, the cells are of a similar appearance to those of the general surface of the membrane, though they seem rather more delicate and transparent.

The projecting edge of the so-called alar ligaments offers still more marked characters. Owing to the congestion of its vessels from some unknown cause, it is frequently seen after death of a bright red colour, its surface is minutely rough or velvety, and its consistence soft or almost pulpy. On examining it with the microscope, many minute and villus-like processes are seen studding its border, and directed backwards towards the commissure of the femoral and tibial articular surfaces. These processes appear to consist chiefly or entirely of two structures, viz. bloodvessels and cells. The vessels are numerous long tortuous capillaries, which pass to the margin of the villus, and then, taking an arched or looped course, return upon themselves, and pass, with few anastomoses, into the general plexus of the fold. The cells, equally with the vessels, resemble those already described as existing at the border of the articular cartilage. They are of various sizes, the more numerous and larger ones are spherical, transparent, and contain a tolerably large nucleus: they are distended with fluid, and the slightest pressure on their singularly delicate cell-wall bursts the cell, and causes the fluid to exude. In this condition, the action of the surrounding water seems to impress on it something like a partial coagulation, giving it a mottled or minutely granular appearance.

The smaller cells exhibit the same shape and general appearances, except that the nucleus is proportionally larger; a few cytoblasts are also present, and a granular blastema completes the covering of the vessels. One would fancy this to be a favourable situation for verifying the existence of a basement membrane, did such a structure exist here; but I have been unable to detect it. On the contrary, I have often seen the curved border of a large cell seated directly on a capillary, the dark line of the wall of this tube alone separating its cavity from the delicate sphere in contact with it.

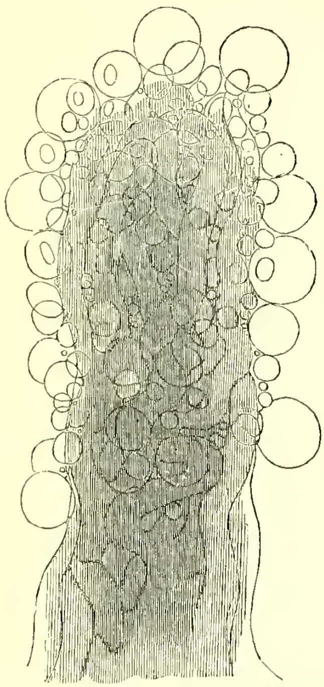
Fig. 401. represents such a villus-shaped process.

The relation of the synovial membranes to the diarthrodial cartilages, or the question of "Whether the membrane is continued over the articular surface of the cartilages, or not?" has been long a matter of dispute among anatomists. But a resumé of the history of this discussion having been already given in an earlier part of the work, the reader is

referred to it for a statement of the arguments on both sides of this interesting question up to that date. (See ARTICULATION.)

The rapid progress of histological anatomy, and the use of the microscope, have since thrown much light on the subject, yet perhaps with a less immediate effect than might have been anticipated.

Fig. 401.



Villus-shaped process from the free Margin of the Alar Ligament. From the Cat. (Magnified 300 *diameters.)*

From the impossibility of injecting the vessels of the synovial membrane beyond the margin of the cartilage, it had long been known that they did not extend over this articular surface; and one might almost imagine that a looped termination of the vessels in this situation must have been suspected. And the researches of Mr. Toynbee* concerning the vascular arrangements of the deep or osseous surface of the cartilaginous lamina, showed a similar disposition of the vessels in this situation. Everywhere a thin plate of bone, impermeated by vessels, separates them from actual contact with the cartilage; and the capillaries themselves, as they approach this osseous lamella, appear somewhat dilated, and finally, taking an arched course, they return upon themselves into the neighbouring extremity of the bone. The truth of this description as a whole is readily tested and confirmed by examining any part of the substance of a diarthrodial cartilage. Such a fragment, torn up in any manner, and submitted to a sufficiently high magnifying power, evinces no trace whatever of vessels, or of their easily recognisable contents.

* Philosophical Transactions, 1841.

But although the absence of vessels is thus proved, the absence of the synovial membrane by no means necessarily follows. The less so, indeed, that modern physiological research exhibits almost all structures as essentially extra-vascular: *i.e.* it shows that in almost all, the characteristic substance of their tissue is separated from their vessels by an interval; an interval which, though always minute, is nevertheless an appreciable, and often a measurable one, and which the pabulum derived from the blood has to traverse in order to effect their nutrition.

The continuity of the synovial membrane, or the reverse, can only be settled in one way; to wit, by an appeal to observation: and since the naked eye fails to give sufficient information, it remains to the microscope to decide its presence on, or absence from the articular surface.

Henle* affirms the continuity of the membrane over the cartilage, as a tesselated epithelial covering of nucleated cells, resembling those which line the serous membranes and the other parts of the joint.

Professors Todd and Bowman in their more recent work†, state that they have been unable to detect such a covering in the adult, but that, on the contrary, they have usually observed an irregular surface, presenting no cells beyond the ordinary scattered corpuscles of the cartilage. In the fœtus, however, they have found it readily visible.

A comparative examination of those cartilages in different genera of animals, or in the same animal at different stages of life, partly confirms, partly modifies, each of these statements.

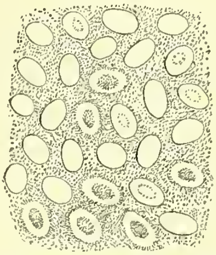
In a specimen of diarthrodial cartilage, taken from an adult mammal, if we make a thin section parallel to the articular surface, and look directly upon this part of the interior of the joint, we see appearances similar to those represented in *fig.* 402. A number of cartilage corpuscles, at irregular distances from each other, and separated by the intercellular substance of this tissue, constitute the only cell-formation visible, and the existence of similar corpuscles at varying depths in the substance of the cartilage may easily be verified. The chief difference noticeable between the deeper and more superficial of these cells is, that those in the latter situation contain in their interior many yellow and highly refractile granules, which are of comparatively uniform size, and occupy their cavity about midway between their tolerably central nucleus and the inner surface of the cell-membrane. This appearance becomes still more manifest as the corpuscles approach the articular surface. A thin vertical section of the cartilage shows that the cells are in greater numbers near this surface, and the edge which borders the joint exhibits an irre-

* Allgemeine Anatomie, S. 226, et seq.

† The Physiological Anatomy and Physiology of Man, vol. i. p. 90.

gular outline, from which cells may often be seen projecting. The attrition which these appearances would seem to denote appears to be exerted upon the cells equally with the interstitial substance of the cartilage, but is more difficult to verify in the former tissue, since such a cell that has suffered a partial destruction of its form, has, at the same time, lost a valuable optical means of detection. Occasionally, however, as in *fig.* 402., on looking

Fig. 402.



Free surface of Articular Cartilage. From the elbow-joint of an adult Cat. (*Magnified* 200 *diameters.*)

directly at the free surface of the tissue, we see a darkish nucleus, lying very superficially, and surrounded by a clear space. In all probability, this was such a cell ground down to a hemispherical cavity. More rarely, a profile view of such a hemisphere is obtained.

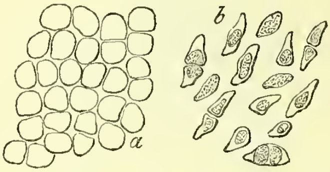
On examining similar specimens from animals of the same species at successively younger ages, the intercellular substance becomes gradually more scanty, and finally altogether disappears, leaving the whole of the surface occupied by a cell-growth, which is a covering, but not an epithelium; unless we extend the application of this objectionable word, and call the whole cartilage itself, what indeed we might with perfect truth, " a modified epithelium."

The accuracy of this description of the cartilage of very young animals is easily verified by a vertical section ; and, if it be made sufficiently deep, it will include a portion of another structure, and a different process, with which it may be advantageous to compare it. At the furthest extremity of such a section, we see the ossification of temporary cartilage actively going forward. First comes the formation of cancelli, and the enclosure of cells; next, a little nearer the articular surface, the greatly dilated cells are arranged in closely-packed rows, the bottoms of which rest in cups of bone, which will soon become cancelli. Still approaching the articular surface, we find the cartilage corpuscles smaller, more refractile, and flatter; but yet with a distinctly linear arrangement. The loss of this arrangement in rows seems to indicate the limit of the ossifying cartilage and the commencement of the articular lamina; and I have often seen the distinction still further marked out by a horizontal fissure in this situation, — the effect of accidental violence, no doubt, but perhaps indicative of some deficiency of cohesion dependent on structure.

Immediately beyond this situation, the cartilage cells are scattered irregularly but closely through the transparent intercellular substance. They are angular and refractile, and they contain a large granular nucleus. Many of them are elongated, and somewhat spindle-shaped, while many more are triangular; and these two forms appear respectively to precede and follow a fissiparous multiplication of their numbers, the constancy and accuracy of which would almost allow of its being termed a bisection. The details of this process have been already alluded to in speaking of the subtendinous bursæ, and are too well known to need any recapitulation here. From hence onwards to the articular surface, the cells become more numerous, larger, and less angular in shape, until finally, on the surface itself, the increase of their number and size results in a continuous layer. But the appearances of this multiplication are not seen in the most superficial stratum of all, although the prevalence of the hemispherical outline still indicates the binary nature of the fission ; whence it seems probable, that just upon the surface the increase is one of bulk only.

In *fig.* 403. is represented a vertical view of the superficial and of a deeper layer, which contrasts them in the particulars just mentioned.

Fig. 403.



Articular Cartilage from a Kitten four days old.

a, arrangement of cells on the free surface; *b*, a deeper stratum. (*Magnified about* 250 *diameters.*)

The condition of these cartilages in the adult fishes and reptiles closely resembles this description of their appearance in the young mammal, in the complete cellularity of their surface. For the knowledge of this fact, I am indebted to Mr. Quekett.

Serous Membranes. — The serous membranes, presenting a structure which offers a close general parallel with that of the preceding tissues, are yet contrasted with them in many important respects. The first and most obvious distinction, and one on which the other structural differences are to a great extent based, is, that in place of their maintaining a direct relation to the *locomotive* apparatus, or being connected with the segments of the skeleton in the diarthrodial joints, the organs to which they are more immediately subservient are those concerned in the *organic* or vegetative life.

The serous membranes of the human body are seven in number ; three being median and single, while two are double and lateral. They are the arachnoid, pericardium, and peritoneum, with the pleuræ and tunicæ

vaginales. Thus they are connected with the organs of respiration, circulation, digestion, generation, and innervation. Perhaps, under this accurate allotment of serous membranes to these several functions, many important analogies lie hidden, but the interpretation of these hieroglyphics of nature scarcely belongs to the present elementary sketch; and it will be both safer and more profitable to regard their relations to the three first of these functions as being determined mainly by the necessity of movement which a high development of any one of them implies, although the general protection which mobility affords must not be lost sight of. The relation of a separate membrane to the function of generation seems, as it were, the accidental result of position: the tunica vaginalis, an offshoot of the peritoneum, is prolonged from it by the testicle in its descent from out of the abdominal cavity, and is subsequently isolated by a degeneration of the serous membrane into areolar tissue along the spermatic cord which connects this gland with the interior of the belly. So the arrangement of the arachnoid around the nervous centre is, perhaps, more related to the comparative delicacy of its structure, and the movements inseparable from circulation, than to the function of innervation itself.

A prominent feature in the anatomy of all these structures is the remarkable continuity of surface which they exhibit. With a single exception, indeed, their interior surface, like that of the subcutaneous bursæ, is everywhere a continuous one; and hence the definition of a serous membrane always includes the statement, that it is "a shut sac," while this peculiarity of arrangement is constituted their "morphological character."

A complete description of the serous membranes would comprise two chief divisions of the subject. One of these would include the relative situation and arrangement of the neighbouring textures, as well as the various folds or processes by which the membranes preserve their continuity in the intervals between the viscera which they cover and the cavities which they line. The other would limit attention to their general structure; and to any variations in the nature, proportions, or arrangement of their constituent tissues, which may be obtained by a comparison of the several membranes with each other. In the present instance, the latter only of these divisions will be briefly attempted; for the former of the two, the reader is referred to the articles under the several headings of PLEURA, PERITONEUM, HEART, NERVOUS CENTRES, TESTICLE, &c.

The *epithelium* of serous membranes consists of flattened cells. The shape of most of these is roundish-polygonal, and many of them closely approximate to the hexagonal form: and they are arranged in a single layer, so as to form a tesselated pavement, which everywhere constitutes the free surface of the membrane. Their diameter varies considerably, but, generally speaking, is about one 1000th of an inch. Their depth is nearly one-fourth of this width; but it tapers away towards the edge of the particle, and is greatest at its centre, where it is usually somewhat bulged by the presence of a tolerably large nucleus, which is contained in the cavity of the cell, but is placed nearer its inferior or attached surface than the opposite or free one. This nucleus is of an oval or spheroidal form, and contains a single bright refractile spot or nucleolus; but not unfrequently there are two of these. Besides the nucleus, the cell includes a small quantity of contents, which are of somewhat viscid consistence, and are usually almost transparent, but sometimes, and especially after exposure to the action of water, become mottled or faintly granular. The attachment of these cells to each other is very remarkable, but their adhesion to the textures on which they are placed is much less considerable; and this preponderance of their adhesion in the horizontal direction renders it very easy to strip off a number of them, and exhibit the layer which they form by their union. In this circumstance they offer a marked and probably important difference from the cells which clothe the interior of bursæ and synovial membranes. Acetic acid exerts its ordinary effects, causing the cells to swell out, and thus defining their polygonal shape more accurately than before.

The exceptions to these general characters are few. In one instance, namely in the peritoneum of the female, the *form* of the cellular covering is said to differ from the above; the ciliated epithelium, which lines the Fallopian tubes, being continued for an exceedingly short distance over the margins of their fimbriated extremities. The *size* of the cells also experiences slight variations: thus, they are largest in the peritoneum, and smaller in the pericardium, especially in its visceral layer. Their *arrangement* as a single cellular stratum is also interrupted in some parts: thus, the arachnoid exhibits one or two layers, the outer of which is composed of cells which are more flattened and elongated than usual.

Basement membrane.—The existence of a basement membrane immediately beneath these cells is still a matter of doubt. It rests chiefly on the affirmation of Professors Todd and Bowman, and Goodsir — high authorities on such a question. By the first of these anatomists it is regarded as "a continuous transparent membrane of excessive tenuity," and "homogenous, or nearly so."* The latter describes it in much the same terms, but considers it sometimes, or generally, separable into component cells, which are of a rhomboidal and extremely flattened shape; and it has been named by him as the *Germinal Membrane*.† As somewhat corroborative of these statements, it may be urged, that such a structure is easily seen to exist in the very

* Op. cit. p. 130.
† Ibid. p. 41.

similar mucous membranes; and that the cell-lining of the arteries, which becomes deficient where these pass into the capillaries, and thus leaves the latter vessels with a simple membranous wall, seems to exhibit a kind of natural analysis of a yet more similar compound structure. And it must be recollected that failure of recognition is by no means a satisfactory argument against the presence of such a delicate structure; *i. e.* that one such affirmation as those above ought to outweigh many denials. Still those who, after repeated and careful examination, have failed to recognise it, are no doubt justified in continuing to doubt its existence.

Areolar Tissue.— A stratum of areolar tissue occupies the outer or inferior surface of the preceding cellular structure, and includes in and amongst its meshes the remaining constituents of the serous membrane. The inner surface of this lamina is smooth and condensed, where it immediately underlies the cells: exteriorly, it can scarcely be considered as possessing a defined surface, but gradually merges into the areolar tissue of the neighbouring organs. The separation of the two structures is, however, generally indicated by an interval, in which their texture is somewhat looser. This is called the "*subserous cellular tissue.*"

As this layer constitutes the chief thickness of the membrane, and is the constituent on which its physical properties are mainly dependent; so its varieties of constitution and arrangement, correlatively with the requisite differences of these properties, are both numerous and important.

One of the most common of these alterations is an augmented quantity of the yellow fibrous element; indeed, in many portions of the serous membranes, this increase is so considerable as to constitute a continuous special layer of the elastic fibre, which occupies a horizontal plane immediately beneath the epithelium. The fibres of this layer are delicate, of a smaller diameter, and somewhat paler colour, than those which are found in the ordinary areolar tissue: they branch at acute angles in every direction, and unite with those in the immediate neighbourhood; while beneath, and partly amongst them, are seen the white fibrous bundles, with their ordinary arrangement. The advantage of such a predominance of the yellow element is obvious: it confers an increased elasticity on the membrane, and better adapts it for distention, or for a return to its original bulk after this force is removed. The situations in which it is found are in exact conformity with this view: in the peritoneum, which lines the anterior abdominal wall and covers the bladder, it attains its maximum; in the detached folds of the mesentery, in the costal pleura, and in the so-called suspensory ligaments of the liver, it is still very prominent; but on the posterior wall of the belly, and in the serous membranes where they cover many of the viscera, such as the heart, brain, lungs, liver, &c., it is almost completely deficient.

On the lungs, the necessity of its presence is probably superseded by the large quantity, both of the texture and of the property, which is inherent in these organs themselves: the remaining viscera are all organs of a size which is either little variable, or of uniform variety.

In the areolar tissue beneath the spinal and cerebral arachnoid, another modification occurs. Between the vascular pia mater, which closely envelopes the nervous centre, descending into its sinuosities of surface, and the visceral layer of the arachnoid, a considerable interval exists, in which the meshes of this tissue are exceedingly long and lax; while, in many parts, the distance between them is so much increased as to form cavities, which have received the name of "the subarachnoid spaces." They are filled with the fluid of the same name; and by its presence the visceral and parietal layers of the serous membrane are maintained in contact, pressure generally becomes equalised, and large portions of the nervous centre hang suspended in fluid. The chief interruption to this arrangement obtains at the summit of the cerebral convolutions, where the arachnoid and pia mater are strongly adherent to each other: but the more minute description of these spaces or cavities belongs to the special anatomy of these membranes.

The fat cells which are so often deposited in the intervals of areolar tissue frequently occupy its meshes in the serous membranes. In most of these instances, however, it would be more correct to regard the subserous or connecting areolar tissue as the seat of the deposit, than that more condensed portion of it, to which an artificial separation would limit the term "serous membrane." It is plentifully found in connection with both layers of the peritoneum, while it is comparatively absent from the arachnoid. In the case of the other serous membranes, the parietal layer is that which is most liable to its presence; indeed, on the lungs, it appears to be completely and invariably absent. This latter circumstance has been ascribed to a supposed local antagonism of respiration to the deposit, analogous to that which is known to be exerted by this process generally. But this supposition seems quite untenable, since the lungs themselves are not nourished by the blood which it is their function to depurate, but by the ordinary arterial fluid, which exhibits the usual changes in the bronchial veins; and one can hardly imagine respiration to exert an influence on the tissue, apart from, or greater than that which it exerts on its blood. Here, as elsewhere, the necessities of movement seem to be the circumstances which chiefly regulate the locality of the deposit: excessive mobility, as in the scrotum, penis, and eyelids, seeming to contraindicate the formation of adipose tissue. The amount present in these membranes generally exhibits a direct relation with that which is contained in the whole body.

The *vessels* of the serous membranes ramify in their areolar tissue, and by their numerous anastomoses with each other constitute a

plexiform arrangement, which occupies, for the most part, a plane parallel to the surface of the membrane. *Lymphatics* in considerable numbers exist in the same situation.

Nerves.— Little is known of the manner in which these tissues generally are supplied with nerves. In the case of most of them, anatomy sufficiently shows that the amount of nervous tissue which they receive for distribution is but small; and at present, even the aid of the microscope does not seem materially to affect this statement. The observations of Purkinje *, and more recently of Volkmann † and Rainey ‡, however, agree in verifying the existence of a large number of nerves in connection with the cerebral and spinal arachnoid. They appear not to communicate with the roots of the spinal nerves, but to pertain exclusively to the sympathetic system; and they branch and form plexuses in the areolar tissue beneath the arachnoid. But how far they are related to this membrane, or the serous membranes generally, or whether they belong more to the pia mater and other subjacent textures, seems at present incompletely determined, and is a question which will require an extended comparison with the other serous tissues.

The very painful nature of the diseases of these membranes is singularly contrasted with the slight amount of sensation of which they are capable in a state of health. It is probable that, as in the bowels, bones, and some other tissues, this contrast mainly depends on the minutiæ of the anatomical arrangements of the nerves relatively to the tissue. In the serous membrane, this may perhaps receive some explanation when we call to mind that almost every morbid change to which they are liable has the immediate effect of converting a smooth, moist, and plane surface into one the nature and disposition of which implies a vast amount of friction, and the abnormal character of which draws this important distinction between it and other normal surfaces which rub with far more force: viz. that no provision has been made to guard against it. And if the arrangement of the nerves, whatever be its other features, allots to them as great a proximity to the surface as is granted to the vessels, it seems tolerably obvious, that any such friction would, in reality, amount to a serious injury of these delicate nervous filaments, and would be quite sufficient to account for the intense pain experienced.

In addition to the preceding tissues included in the ordinary enumeration of the serous membranes, there are other parts of the body which present structures so closely resembling these, as to render it perhaps doubtful whether this title can justifiably be withheld from them. The ventricles of the brain are lined by a membrane which exhibits the characteristic smooth and shining appearance of the serous tissues; the posterior surface of the cornea is occupied by a similar layer; and, according to Henle, there are considerable grounds for conjecturing the existence of some such structure on the inner surface of the membranous labyrinth and semicircular canals. But without here entering into the question of a possible transition of mucous into serous membranes being represented by these tissues, it will be sufficient to point out that while the ventricular and corneal membranes present a stratum of epithelial cells analogous to those described above, they are almost or entirely deficient in the important element of areolar tissue, — and that this constitutes a difference according to which the line of distinction is drawn, excluding them from the serous membranes. The epithelium which lines the general surface of the cerebral ventricles consists of flattened polygonal cells which are covered with ciliæ; but where it passes over the choroid plexus, it varies so considerably from this description as to merit a special notice.

The *choroid plexus* occupies the descending cornua of the lateral ventricles, and forms the margins of the velum interpositum, the intimate structure of which it resembles in many respects. It consists chiefly of an interlacement of capillaries and capillary arteries. The former are of large size and great tortuosity; and, in this last respect, they are similar to those of the synovial membrane already described. A little areolar tissue surrounds and supports the vessels, and a stratum of cells covers the surface of the plexus. Besides these structures, a large number of nerves have been described by Mr. Rainey as ramifying beneath the cells, but Purkinje and other observers deny the existence of nerves in this situation. Concerning the shapes of the cells which cover the plexus, similar differences of opinion and description obtain; Henle*, Valentin †, and other high authorities speak of them as being in general polygonal, but somewhat flattened and curved where they cover the fringes of the plexus; while, on the other hand, Mr. Rainey attributes to them a spherical shape and faintly granular contents. The following are their appearances as noted by the writer of this article.

At the margins of the fringes are seen many long and tortuous capillaries, the general course of which is parallel to the border of the plexus, and interrupted by few anastomoses. No basement membrane can be detected interposed between these vessels and the cells. The cells themselves are of a spherical shape, and of the very large size represented in the sketch (*fig.* 404.), many of them being one five-hundredth of an inch in diameter, a magnitude rarely paralleled by any cells but those of the adipose tissue: they contain a tolerably large nucleus in contact with their inner surface. Where exposed to the slightest pressure, they take a polygonal shape, but I

* Müller's Archiv. 1845.

† Wagner's Handwörterbuch der Physiologie, artikel "Nervenphysiologie."

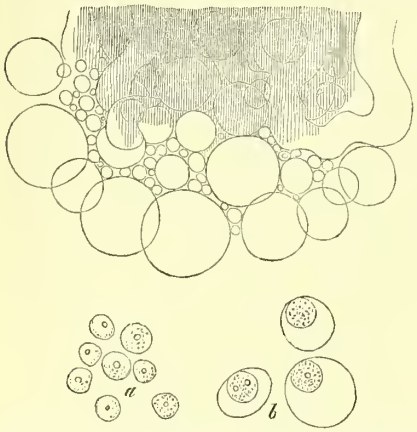
‡ Medico-Chirurgical Transactions for the year 1845.

* Allgemeine Anatomie, S. 228.

† Wagner's Handwörterbuch, artikel "Gewebe."

have never seen such an appearance except under these circumstances; and at the edge of the fringe, which is usually more or less shielded from pressure by the prominence of the neighbouring surface receiving the weight of the upper lamina of glass, this perfect globularity is readily verified. The cell-wall is extremely delicate and thin; its contents are

Fig. 404.



Cells of the Choroid Plexus. From the adult Cat. The upper figure represents their arrangement in situ; in the lower, *a*, nuclei of ruptured cells; *b*, cells detached. (*Magnified* 320 *diameters.*)

fluid, and usually nearly transparent, and of a refractility not much different from that of water. So great is the delicacy of the membrane, and so little aid to observation is given by its colour or refractility, that at first it requires careful scrutiny before its presence is verified; and its recognition is often retarded by the excess of light which the modern achromatic condenser affords. From this, which is the ordinary size, they pass by few gradations to a plentiful blastema, which fills up the interstices, and more or less completes the covering of the vessels. On tearing up such a fringe, most of these cells disappear, and their collapsed membranous walls may be found here and there, flattened and folded upon themselves, or burst at one extremity, and giving vent at the rupture to a faintly granular mass and their nucleus. The nuclei found in multitudes in such a specimen are round and pale, and contain granular matter and a single small bright yellow nucleolus; or, rarely, there are two such spots. Many of these free nuclei exhibit a flattened or truncated surface, which indicates the extremity previously seated on the inner surface of the cell.

Whatever may be the import of this peculiar structure, it is interesting to observe how closely, both in the arrangement of the vessels and the structure of the cell-covering, it resembles the synovial fringes previously described. The view of Mr. Rainey, that these spherical cells are nerve vesicles, seems to rest at present on the very insufficient basis of a slight external resemblance. But it appears difficult to infer such complicated functions as are sustained by the nervous matter from such simple physical properties as sphericity, faint granularity, and the like, unaided by other structural analogies.

Development of serous membranes. — The steps of this process are little known, a circumstance which seems partly to depend on the extreme readiness with which it occurs, partly on the comparative simplicity of its nature: the cell being retained as the permanent form of the tissue, the mere apposition of a number of these in connection with a surface of areolar tissue is all that is required to complete the visible phenomena of its development.

In the animal kingdom, serous membranes are almost invariably present. They mostly appear in immediate connection with some higher development of the several viscera around which they are grouped. In this manner, first the peritoneum, and next the pericardium and arachnoid, appear. The first indication of the pericardium is in the mollusca, and its appearance seems to be immediately preceded by a mechanical provision of a very different kind, although perhaps of similar import: the heart is suspended in the centre of a muscular cord, which is attached by its two extremities, and thus fixes the viscus and steadies its movements. The peritoneum and pleuræ are united in one in the reptiles; afterwards, the latter membranes are shut off by the formation of a diaphragm. The tunica vaginalis is absent in those animals, in whom the testicles occupy a position within the belly.

Generally, there is the same obvious relation of their presence to mechanical uses which is seen in the human subject. But the ciliated serous membranes of many reptiles, and the urinating pericardium of cephalopods, offer, at present, such great and inexplicable differences from the human serous membranes, that one might almost doubt, especially in the latter of these instances, how far textures contrasted by such manifest differences of structure, and probably of function, can justifiably be called by the same name.

In the human fœtus, their development is also little understood. This period of life, however, adds the amnion to the list of serous membranes, the structure of which it closely resembles. Its cavity is occupied by a saline and albuminous fluid in large quantity. It is subject to fluctuations in amount, and one or two analyses appear to show that the proportion of albumen which it contains is considerably diminished in advanced pregnancy.

Development by friction. — Besides these two forms, the development of some of these structures is witnessed in another condition, perhaps more peculiar than either; viz., in answer to the application of mechanical force. The subcutaneous bursæ which are ordinarily found over some of the various prominences of bone indicate the nature of their relation to these localities by their reproduction after

excision; while in other situations of the same kind, but in which they are not usually present, the application of long-continued pressure and friction gives rise to their production. If we add to these phenomena the development of diarthrodial false joints, it will appear that a certain amount of pressure is capable of determining the formation of a cavity, and the growth of a cell-covered membrane, which secretes a synovial fluid; and that, exerted in a higher degree upon the more resisting bones, it clothes their extremities with a substance which presents all the appearances of cartilage. The presence of blood plasma is no doubt a necessary condition of both processes, but in neither are the subsequent minute changes known. In the case of the areolar tissue which is converted into a bursa, we may indeed infer, that mechanical violence exerted upon it would produce an increase of vascularity or an active congestion; but we can scarcely conjecture how this alone should result in an increased *vital* activity, in the removal of some of the partitions of its net-work, the compression of others, the formation of a cavity, and the regular cell-covering of its inner surface.

But while the production of this structure in answer to pressure is exceedingly interesting, and offers a remarkable analogy to its general development in the fœtus and animal kingdom, there is perhaps a danger of our exaggerating the resemblance, and becoming too mechanical in our views. On closer consideration, their ordinary and extraordinary formation will be found to exhibit a difference, which may teach us caution in our conclusions as to the method in which mechanical force acts. It is this: that while, in the latter case, their development appears to provide for a want already experienced; in the former instance,—in the young embryo,—we may observe a very similar development occurring, which is a provision for a necessity that has never yet existed, and cannot therefore be the immediate cause.

Physiology of the serous and synovial membranes. — At present, the physiological import of the preceding minute structural details is so little recognised or understood, as to leave scarcely anything to be said under this division of the subject. But, in this respect, these textures present so close a parallel to many others in the human body, that to consider this imperfect knowledge as demanding a complete silence, would be to interpose an insuperable barrier to almost all conclusions on any physiological subject. In truth, the question of the abstract truth or falsity of physiological conjectures by no means involves the question of their usefulness; and the difficulty of retaining mere details, the danger of considering them as essentially knowledge, the possibility of allowing a philosophic suspension of judgment to merge into slothfulness,—all these circumstances taken together perhaps claim that such anatomical minutiæ should at least be considered with a view to their explanation; even while they demand that the various shades of probability possessed by these conjectural explanations should, as far as possible, receive their due estimation; and that their adoption should never interrupt the collection of fresh facts.

Some attempt has already been made to discriminate between the physical and vital properties of these membranes; and the mechanical advantages conferred by some of the former were enumerated as constituting their most prominent use. Their secretory *function* has next to be considered, together with any relations which this process may possibly bear to the organism generally, as the further *use* of these structures.

A most important feature, and one which belongs to all these membranes, is their peculiar arrangement. The general statement, that they are so disposed as to form shut sacs, has been already alluded to, and was at no late period considered their characteristic definition. But as mere form could scarcely be thought of such essential importance, various attempts have been made to explain this morphological character, by referring it to some other term, which should either express a real cause, or should approximate to this by enunciating some physiological purpose itself implying the fact. Many of these, however, such as its being the result of the universal presence of epithelium, &c., are little more than re-statements of the fact in another form. But to the exception of the female peritoneum, long known, must now be added (unless the definition of these structures be arbitrarily extended so as to include many varieties of cartilage) all the articular synovial membranes, and many of the bursæ; in which the interruption to the continuity of the membrane constitutes the phrase "shut sac," an inaccurate expression as applied to them.

In short, all that the term really implies is, that there is no visible outlet by which the cavities these tissues form, or assist to form, can communicate with the exterior of the body. And even in the case of the apparent exception at the extremity of the Fallopian tube, it is exceedingly probable that the small size of the aperture of communication, the ciliated lining which it possesses, and the direction in which the current of ciliary motion sets, constitute it, in effect, a closure. The internal position of the serous membranes is followed by this important physiological consequence, that the contents of their cavities are never directly eliminated from the body; but that such portions of the substance of the membranes, or of its separated products, as may become effete in the course of the vital changes, can only be discharged from the system after a previous reception into the general mass of the circulating fluid. This fact at once establishes a broad line of distinction between these tissues and the mucous membranes, or true glands; while at the same time it tends to prove that their secretion, whatever it may be, possesses little of the deleterious quality, or excretory

composition, which marks many of the products of the mucous system.

Contrast of serous and synovial membranes. — The shape of the cell of serous membrane may afford some indications of its history. In flatness, it occupies a position about midway between the squamous outer epithelial particles of the skin, and the columnar intestinal cells. The conditions which lead to the excessive horizontal extension of the former appear to be, a vertical pressure acting upon them during their growth, and aided by an evaporation which diminishes the cell-contents, themselves originally small in quantity. On the other hand, the immediate cause of the prismatic or columnar shape is, no donbt, a horizontal pressure mutually exerted by the growing cells themselves. This pressure appears generally to limit their diameter to that of the contained nucleus; a smaller diameter, which implies the existence of a greater number of cells in a given space. Their longitudinal extension similarly involves a greater amount of contents; so that, on the whole, this might be termed the highest form of cell-growth, the development and filling of a large number of cells simultaneously.* Comparing the serous epithelium with these two extremes, we may recognise in its flattened shape the effect of vertical pressure on a cell containing but little in its cavity; while the comparatively small number of cells in a given space, and the oneness of the layer, are further indications of the moderate activity of the cell-growth. The uniform size and polygonal shape of the constitnent cells, together with their great mutual adhesion by their edges, or in the horizontal plane; — these are circumstances which seem to point to the simultaneous development of the whole layer, and to the previous causes of flatness determining its growth almost exclusively in this direction.

The little aid afforded by the composition of these cells is derived from observations which are chiefly of a negative kind: since they show that the cells do not offer any considerable chemical differences from the liquor sanguinis, but consist chiefly of albuminous and fibrinous materials.

The nature of the serous secretion seems little understood. In health, the quantity of fluid present in the interior of the membranes is only sufficient to moisten their free surface; while where its amount is enough for the purposes of analysis, the accompanying diseased conditions would prohibit our assuming its identity with the normal fluid, even if the supposition were not rendered untenable by the varying composition of the fluids themselves. But, on the whole, the very small quantity of fluid naturally present, its comparatively limpid consistence and transparent appearance, together with the absence of the cell-form in which secretions are involved, probably refer it immediately to the simple physical process of transudation; a process which is present everywhere in the body, but is favoured by the thin parietes of these structures, while their position prevents the removal of the fluid by evaporation.

But the fluid yielded by this supposed process appears to be chiefly aqueous; and the question therefore readily suggests itself, whether any mere transudation could filter off the dissolved constituents from a perfect solution, such as the liquor sanguinis is known to be; and whether the elective affinities of the tissue itself may not constitute the main agents of the process, by retaining certain materials, and allowing others to obey this physical law. Valentin * mentions some experiments in which dried serous membrane was used as the filter, and albumen, so far suspended in water as to constitute a homogeneous fluid under the microscope, was passed through it. The result was, that it retained a thicker portion, while only a thinner or more dilute part passed through. But saline solutions transuded entire, and perhaps the doubtful state of solution of the organic constituent will not permit much reliance to be placed on these experiments. In connection with this subject, Mr. Paget † has pointed out that the different serous membranes seem to effect this "filtration" with different degrees of fineness. And, possibly, the diminution of albumen noticed in the liquor amnii of advanced pregnancy may be ascribed to a similar subtraction from this fluid by the serous membrane in the cavity of which it is situated. The share which the cells as such take in this process can scarcely be conjectured; but that their disposition in such a form is not absolutely essential to the fluid, is shown by its occurrence in the areolar tissue, where such a stratum is absent. And while we know next to nothing of the process itself, and have no name by which it may be exclusively indicated, it is important to recollect that the words used above, "elective affinity," "subtraction," "filtration," are probably alike inaccurate; that the first seems to imply chemical combination, the second represents the subtracted materials as too passive, the third is the name of a physical process by which solid objects are left behind after the removal, by capillary attraction, of the fluid in which they were suspended. The processes to which it seems most analogous, and to which it may best be compared, are those curious varieties of heterogeneous adhesion existing between bodies of different cohesive forms, of which the action of charcoal or platinum upon certain gases are familiar instances

The period of duration of the cell-growth, and the manner of its renewal, can only be conjectured. But from the constant absence of shed epithelium from the interior of the membrane, and the uniform shape and mutual

* For some further remarks on the subject of cell-growth, the reader is referred to a future article, "Stomach and Intestinal Canal."

* Lehrbuch der Physiologie des Menschen, Band 1., S. 601.

† Report on the Progress of Human Anatomy (Brit. and For. Review, year 1843-4, p. 10.)

adhesion of the cells, one might imagine that the stratum ordinarily lasts a considerable period without experiencing any desquamation or substitution of new cells. And although the ease with which a layer of cells is stripped off by slight force might at first sight seem opposed to such a notion of their durability, yet it is tolerably certain that the mechanical relations of the cells are so adjusted as to allow the free gliding movements of their moist, smooth surface with perfect impunity. While, on the other hand, where the presence of the tissue seems to fulfil its main object, a mechanical one, and where the flattened epithelium does not include the elements of a secretion in any quantity, and consequently would hardly fulfil any secretory purpose by its occasional or exceptional separation; to what purpose should it be ever shed at all? The serous membrane exhibits one layer of solid cells, all of which are related by one (the nucleated) surface with the neighbouring vascular supplies, while they present their opposite surface to receive a slight friction; and it does seem possible that the effete materials may be removed, the losses of friction made up, and, in a word, the gradual exchange which constitutes the nutrition of a tissue accomplished, without the disruption of the old cell and the substitution of an entire fresh one. The cell-form does not necessarily imply evanescence, and the centre of attraction which it constitutes can hardly be supposed unfitted for the processes of ordinary nutrition, because it sometimes collects materials which imply its destruction, or is thrust away from the sources of nourishment by its fellow vesicles. And if it should be asked, "Why is the serous membrane constituted of cells, if the ordinary form of nutrition would suffice?" it might be pointed out that, although the form of nutrition be the same, its pace may and probably does attain a greater rapidity in cells than in the more permanent textures, and that by their instrumentality the rubbing surfaces are everywhere separated by an appreciable interval from the delicate capillaries, a condition that could scarcely obtain in areolar or ligamentous tissue, however it were disposed; and that in addition to this, cells offer the mechanical advantage of forming a smooth tesselated pavement, while they possess the physiological merit of readily repairing the accidents to which this tissue seems comparatively more liable than others.

The *synovial membranes* seem to differ from the serous membranes in most of these respects. The cells which cover the general surface of the membrane are more spherical, less uniform in size, and less accurately tesselated; while on the highly vascular fringes, the large, globular, and distended epithelia, with their plentiful blastema, strengthen the indications of active secretion thus afforded. The presence of synovia in considerable quantity, and the recognition of the ordinary secretory process, by the detection in it of relics of cells, chiefly nuclei, form another ground of distinction. This secretion of viscid fluid appears to be indirectly referrible to the greater pressure exerted on these surfaces, and the consequent necessity of a further protection against friction; while it is no doubt immediately the result of the separation of this active cell-growth, alone, or accompanied by fluid derived from the vessels. The bursting of the distended and delicate cell is probably the agent of the separation, and may be due solely to a distention beyond the physical power of resistance which its wall possesses.

The resistance of the cells on the general or capsular part of the synovial surface, and the irregular and isolated manner in which force detaches them, have been previously noticed, and contrasted with the facility of removing the whole layer of serous cells. They seem to denote, not only a mechanical adaptation to greater friction, but perhaps a corresponding independency of the cells, which possibly form a continuous and active growth, scarcely any two portions of which are exactly of the same age.

And not only is the secretory activity of these membranes much greater, but there is every reason to suppose their absorptive functions are still more increased. Assuming, from the preceding appearances of active cell-growth, that a greater quantity of fluid is secreted by them into the cavity of the joint than the amount of serum which finds its way into the interior of the serous membranes; — since only a tolerably uniform and small quantity is discovered to be present there,— it will follow, that the rapidity of its removal has corresponded with that of its introduction: and as this removal cannot be attributed to any other cause than that of absorption, we must therefore regard its increase as parallel with the increase of secretion.

But there is another circumstance which renders it likely that the former of these two processes is even disproportionally greater. However carefully the surfaces of diarthrodial cartilage may be lubricated by the synovial fluid, a very slight knowledge of mechanics would inform us, that some friction of these must of necessity obtain; and that from the conditions of its density, homogeneous nature, &c., it is probable that the amount of this is, though diminished, yet by no means inconsiderable. So also, from the structure of this substance, it is physiologically probable that its tissue grows towards this surface, and that the arrival of any one particular portion at this point is, mediately or immediately, the cause of the termination of its existence. While the anatomy of this free edge abundantly confirms the fact of such an attrition: vertical sections show an irregular border, from which some cells are seen slightly projecting, while others appear (as in *fig.* 402) ground down to its level.

Whatever be the amount of cartilage which is thus rubbed off and set free in the cavity of the articulation, or whatever may be the cohesive form which it assumes, the thick and solid cartilaginous lamina which is interposed between this "débris" and the

vessels at the osseous surface (the vessels to which in the first instance the formation of the tissue was due) seems to constitute an effectual barrier to the performance of its absorption by them. And since the process no doubt occurs, the only remaining vascular surface, or that of the synovial membrane, is clearly indicated as the agent by which it is effected.

Hence, the synovial membrane possesses, so to speak, a *double* absorptive function: one, which is essentially its own, counterbalancing the active progress of secretion, of which it is the seat; another, which is, as it were, delegated to it by the cartilage, and is the result of the physical incapacity of the latter tissue.

And in a sketch of the morbid anatomy of these structures which occupies the subsequent part of this article, it will be seen that the mutual dependence thus supposed to exist between the articular cartilage and synovial membrane in health, finds, in all probability, a close parallel in some forms of disease. The chief difference noticeable here is, that the preliminary breaking up of structure which appears to be chiefly physical or attritional in the normal cartilage, is a vital process which is inherent to the diseased texture.

The *subcutaneous* and *subtendinous bursæ* present a similar fluid, which is usually in much smaller quantity. They seem, in most of the preceding respects, placed midway between the serous and synovial membranes; but many of the preceding remarks, mutatis mutandis, are applicable to them.

The close resemblance of the *choroid plexus* to the synovial fringes was pointed out in speaking of the former structure: but it is obviously almost impossible to conjecture a similar mechanical import of its secretion; nor, indeed, have we any reason for asserting the separate existence of a fluid secreted by it.

In respect of their internal situation, all the preceding tissues resemble that recondite class of structures, the glands without ducts; and their similarity of form has also a physiological parallel;—viz. that all their constituents are returned into the blood, either unchanged in their composition, or elaborated, or effete. They differ from them, however, both in the greater perfection or maturity of their cell-form, and in the lesser activity of their secerning power.

In the degree, and perhaps in the nature, of this resemblance, some distinctions may be drawn. Thus, the *serous* membranes, in the possession of a solid attenuated epithelium, and in the probable absence of a secretion, are at the lowest or most distant extremity of the scale; raised very little above areolar tissue. The *synovial* membrane, with its much more active cell-growth, and its fluid secretion, comes somewhat nearer; albeit, the secretion seems mainly developed in answer to the mechanical requirement of a lubricating fluid. Still, the possibility of a less physical function of both these tissues must not be lost sight of. In the *choroid plexus*, the approximation is made yet more close by the negation of this mechanical import; and we are left in complete doubt, whether it is a provision for quantitative or qualitative fluctuations in the blood which supplies it; whether, in either of these cases, the cell-growth operates a chemical change or elaboration on the materials submitted to its action; or, finally, whether it returns these to the circulation, or surrenders them at once to the neighbouring nervous tissues.

Morbid Anatomy of Serous and Synovial Membranes.—The following sketch of the diseased appearances of these tissues is necessarily limited to their more general features. At present, it is scarcely possible to discriminate between the very analogous pathological conditions of the two classes of serous and synovial membrane; although it is probable that an advance of knowledge will at no distant date enable us to do so. And even where the distinctions of appearances are sufficiently palpable, our ignorance of their general nature allows few inferences to be drawn from these varieties.

Thus, the remarkable immunity from mechanically-produced effusions which the synovial membranes enjoy is little understood, although one may perhaps doubt whether it is quite so complete as it is generally supposed to be. The only conjecture that seems at all probable is, that the nature and activity of the cell-growth which covers their surface may have some relation to the difficulty with which such fluids transude. So, also, the comparative infrequency of adhesion in their inflammations is, at present, a vague fact, the cause of which is unknown;—it may either be referred to an explanation similar to the preceding, or may, as Professors Todd and Bowman suggest*, depend upon the presence of a viscid secretion in their interior.

Serous or dropsical effusions.—One of the most frequent of the morbid appearances seen in these tissues is the presence of a serum-like fluid in their cavity. It occurs in a very large number of deaths from various diseases. In most instances, however, the serous membrane only shares in a dropsy which is common to other structures, and especially affects the areolar tissue. Thus, for instance, where death has resulted from some mediate or immediate obstruction to the passage of blood through the right cavities of the heart, and has been preceded for some time by general anasarca, it is usual to find a considerable quantity of fluid occupying the pleura, peritoneum, and other serous membranes. In other diseases, as in cirrhosis, the serous effusion is not only a more direct result of a greater venous obstruction, but it also assumes a higher import than in the previous instance, and becomes both of earlier occurrence in the history of the dis-

* Physiological Anatomy and Physiology of Man, vol. i. p. 131.

order, and of weightier influence upon its termination. Here, an accompanying dropsy of the areolar tissue is less frequent and prominent, but it still generally follows at a certain stage of duration and intensity: it is usually ascribed to the pressure of the distended belly acting upon the vena cava, and producing a secondary dropsy from the branches of the systemic circulation which join that vein.

In another class of cases, the serous effusion is still common to the areolar tissue and the serous membranes, but it arises from a different cause; one which is no longer a mechanical impediment, but a chemical alteration. The dropsy of chlorosis is a good example of this species of effusion, and to it may probably be also referred that seen in the latter stage of phthisis and other exhausting disorders. Analysis shows, that in these *anœmiæ* the blood is rendered much poorer by the loss of a considerable proportion of its albumen, and the serum of the thus diluted fluid possesses a greater tendency to transude the membranous walls of the vessels, and pervades the surrounding structures in an undue quantity. Below a certain percentage of albumen, Andral affirms the occurrence of dropsy to be tolerably constant.

To these two classes may be added a third, in which serum is found in these structures without any sign or symptom of its presence having been detected during life. These cases are so numerous, that, even after subtracting a considerable number as possibly due to neglect or difficulty of recognition during life, a large number still remain, in which the effusion may be fairly presumed to have taken place after death. And in many instances, they are not only affected by gravitation, but, like the very analogous condition of the areolar tissue, their occurrence seems to be favoured by it. Yet, as such appearances are absent from a large majority of post-mortem inspections, it will follow, that the effusion of this fluid is to be ascribed, at least in part, to some conditions other than mere gravity. These are probably similar to the circumstances which conduce to the production of the preceding class of effusions, a deficiency of the albuminous constituent in the blood, or, with lesser likelihood, the condition of the walls of the containing vessels themselves. They thus appear to be due to both a mechanical and chemical affection of the blood, and so seem to offer an union of the two causes to which the preceding classes have been severally ascribed.

Many of the serous fluids which are found in the ventricles of the brain and beneath its arachnoid membrane, offer sufficient distinctions in their nature and causes to merit recognition as a separate variety. They are alike independent of physical obstruction of the vessels, or of a qualitative alteration of their contents; while their quantity, which is frequently a considerable one, and the corresponding diminution of the size of the brain, together clearly indicate that they are not due to mere post-mortem phenomena. But while, on the one hand, they are unattended by these, the ordinary causes of such effusions, and are devoid of all symptoms which would indicate them as in themselves morbid; so, on the other, they are not present in the healthy subject. Hence we may deduce, first, that they are related to some abnormal condition; and secondly, that this relation is not an immediate one. This may be confirmed by considering that the organ bathed by these fluids is one which, from its physical and physiological properties, its soft consistence and important functions, is both peculiarly susceptible of disturbance from pressure, and ready to give signs of such disturbance; so that the absence of these indications betokens a nicety of adaptation of the fluid to the cranium and its contents which is hardly to be explained in any other way than by supposing that this adaptation is itself the object which the presence of the serum fulfils, or that the want of it is the condition which necessitates the effusion, if indeed it does not more immediately give rise to it.

In the cerebro-spinal fluid itself, we are presented with a more normal counterpart of this scarcely morbid effusion; since a fluid of similar constitution, in lesser quantity, is here a constant phenomenon. In the loose and vascular areolar tissue between the arachnoid and the spinal cord, this perpetual dropsy is the natural condition of the part; and is perhaps due to the greater mobility enjoyed by the vertebral column where it surrounds these parts of the nervous centre, a freedom of movement which requires that they, in their turn, should be more carefully protected from external violence.

Physical and chemical properties. — The appearances of the fluid found in the circumstances above mentioned are tolerably uniform, and the few variations that occur are chiefly of an accidental nature. It is usually a limpid, colourless, and transparent fluid, of a faintly alkaline reaction; and, in a state of purity, it offers no trace of organization, either to the naked eye or the microscope. In its consistence, however, it is susceptible of great differences. It varies from the limpidity of water to the viscidity of synovia; and when containing very much albumen, is sometimes even thicker and more tenacious than this liquid. Its colour is very frequently and greatly affected by admixture with blood, bile, and other matters; or by the partial precipitation of its albumen; or, more rarely, by the solidification or crystallisation of fatty constituents. Many of these causes also affect its transparency, giving it more or less opacity, as well as colour. Its alkalinity is less liable to variation; but occasionally it is neutral, and very rarely acid. Its unorganized character is only interfered with by accidental impurities similar to those above noticed.

The chemical composition of these fluids is much more variable; indeed it is very probable that scarcely any two of them are

exactly alike in this respect. The following table exhibits four analyses, contrasted with that of the serum of the blood: —

	Serum of Blood.	Phthisis.*	Ascites.†	Ascites.	Ascites.
Water - -	905	988	988	956	704
Albumen -	78	3	0·9	29	290
Extractive -	4·2	} 9	10	9	2
Fat - -	3·8			7	
Salts - -	9			8	4
	1000	1000	998·9	1009	1000

The difference in the amount of albumen which these analyses exhibit is very striking; and the large quantity present in the latter is especially remarkable as offering nearly four times the quantity which is present in the serum of the blood. The anomaly of an unorganized liquid, derived from the blood, possessing more of this important constituent than the parent fluid, has been attributed by Vögel to a reabsorption of the watery parts subsequently to the effusion. The varying methods of analysing these fluids leave less room to remark quantitative differences of their other constituents. The quantity of salts seems, however, pretty constant; although the following analysis ‡ exhibits a singular increase in one of the most common saline ingredients. It was taken from the dropsical belly of a woman aged 40, and the urine is stated to have contained about 6 parts in the 1000 of the same salt.

Water - - - - - - -	950
Extractive, with traces of albumen -	5·97
Fat - - - - - - -	·84
Almost pure chloride of sodium -	44
	1000·81

The small number of analyses hitherto made, and the incompleteness of the pathological notice with which they are usually accompanied, render it at present too early to arrange the composition of these fluids in any real connexion with the various morbid states which have regulated their production. But the possible cause of an excessive preponderance of albumen has been already alluded to, and on the whole it seems likely that the cases where this substance is of a less remarkable, but still a considerable amount, belong chiefly to the category of dropsy from mechanical obstruction; while the dropsies of anæmiæ, post-mortem transudation, and the like, seem to be characterised by the possession of a very small quantity of albumen: thus the second analysis in the table exhibits only three parts in the thousand; and two or three others are given by the same author, which have a very similar composition. In the serous fluids of the cerebral ventricles, the quantity of albumen appears still smaller, as is exemplified in the following analysis by Berzelius.*

Water - - - - - - -	988·3
Chloride of sodium and potassium -	7·09
Albumen - - - - - -	1·66
Lactate of soda, with alcohol extract -	2·32
Soda - - - - - - -	·28
Extractive, with traces of phosphates	·35
	1000·00

In respect of their diminished quantity of albumen, it is difficult to avoid noticing their approximation to the characters of the cerebro-spinal fluid, the vitreous humor, and other healthy effusions.

The question that next suggests itself is, "What relations do these fluids bear to the serous membranes?" From a comparison of the analyses quoted above, it is sufficiently obvious that amid multiform phases of composition all these fluids preserve a close resemblance to the serum of the blood; a feature which sufficiently testifies to their origin and import, and which refers their production to the conditions of the blood, and their consideration to the pathology of this fluid, rather than to the serous membranes in contact with which they are found. And the bearing of this evidence is corroborated by several other facts. In a vast majority of cases, as above mentioned, their occurrence may be directly traced to blood disorders; either a qualitative affection of this fluid, or a mechanical distention of its containing vessels,— a mutual dependence which tends still more to allot them to the blood rather than to the serous membranes. Again, instead of their presenting the cellular form, in which the elements of secretion, morbid as well as healthy, are usually involved, and which they might be expected to assume were they essentially the product of the cell-growing membrane, they are devoid of all appearances of such organization. While in place of being peculiar to these membranes, it is found that an identical effusion obtains in the areolar tissue; a structure which is alike destitute of their membranous form and epithelial covering.

Inflammatory or fibrinous effusions. — A large number of the fluids which are found effused in the interior of the serous membranes offer characters which essentially distinguish them from the dropsical effusions above described. The first and most prominent differences are those presented by their *appearance* and *chemical composition*. In addition to the albumen and salts which form the main constituents of the serous effusions, they also offer a greater or lesser quantity of fibrine; and as this substance retains its ordinary power of spontaneous coagulation, its presence is readily recognized by the eye.

* Reduced from an analysis by Karl Frua. Heller's Archiv., 1845, S. 363. The fluid was found in the abdominal cavity.

† An analysis by Vögel, from whose "Pathologie" the remaining analyses by von Bibra, Dublanc, and Lecanu, are quoted at second-hand.

‡ Heller's Archiv für Phys. und Path. Chemie, 1844, S. 47.

* Simon's Chemie, Band ii. § 581. The case is mentioned as "Hydrocephalus."

To these physical differences accede equally important pathological grounds of discrimination. The effusion of the fibrinous fluid is usually attended by more or fewer of those symptoms, the aggregate of which is known by the name of *inflammation;* and in the few instances where these external indications are absent, the presence of the fluid is itself considered sufficient evidence of the previous occurrence of the inflammatory process; while the mechanical causes, which often appear mediately or immediately to determine the occurrence of the simply albuminous effusion, seem to have no influence in the production of these phenomena. Lastly, the fibrinous effusion is distinguished by this important quality, that it is susceptible of organization, or capable of an apparent conversion into tissues, the structure of which closely approximates to that of some one or other of the normal and permanent textures of the human body.

The class of effusions characterised by the possession of the common properties of fibrinous composition, inflammatory origin, and susceptibility of organization, is a very large one, and includes a great variety of fluids. The extremes of these numerous gradations offer some contrast; in one the symptoms of inflammation are well marked, and the effusion chiefly consists of matters which are plastic: *i.e.* which pass rapidly from a fluid state, through that of an uniform pasty mass, into a solid form; and which for the most part experience a rapid and complete organization, being converted either into pus or into some more permanent structure. In the other subdivision, the symptoms of inflammation are usually less marked, the fluid contains less fibrine, is less susceptible of organization, and not only remains chiefly fluid, but, in a large number of instances, does not deposit any part of its contents in a solid form until subsequently to its removal from the living body, or after the death of the patient.

In the earliest stage of inflammation, and before effusion has yet occurred, the morbid appearances of the serous membranes are limited to an injection, or active congestion of their vessels. Most of these, it will be recollected, are arranged as a flattened plexus in the areolar tissue which forms so large a part of the membrane; and the injection of this plexus, at first in isolated points, and afterwards in larger patches, gives to these parts of the free surface a heightened red colour, which is clearly visible through the thin and almost transparent layer of cells, alone intervening between the capillaries and the interior of the membrane. But although a superficial, patchy, and well-marked redness, dependent on congestion of the minutest vessels, constitutes a tolerable presumption of the presence of inflammation, yet such a state can be so closely imitated by conditions which are not inflammatory, — such as a merely passive venous congestion, due to position of the body, mode of death, and a variety of other causes, — as to be, in a majority of cases, of little value as evidence of this process. And even in instances where the symptoms during life have rendered the existence of inflammation probable, an examination after death has often detected no such appearance; whence it would seem that this vascularity is capable of disturbance or removal, either during the phenomena of death, or after that event has happened. And it is also to be noted, that the different serous structures seem liable to this appearance in a very different degree: some, as the arachnoid, scarcely ever presenting any trace of such a suffusion; while in others, as the pleura, it is much more frequent. So that, on the whole, it may be stated that neither does its presence affirm, nor its absence deny, the occurrence of inflammation; still less, where present, is its amount to be considered any measure of the intensity of the process.

An alteration in the texture of the membrane itself is probably immediately subsequent to this injection in the order of time, and is generally seen in connection with it. Its surface, instead of the smooth and shining appearance which it ordinarily possesses, becomes dull and dim, while it is dry and almost rough to the touch; and at the same time the thin and transparent expanse of its texture acquires a milky opacity, and an increased thickness, which in the more delicate serous membranes is especially well marked. The former of these appearances probably indicates some affection of the epithelium, which clothes the free surface of the membrane; but the latter is due to the commencement of effusion. This process begins where we should naturally expect it, viz. in the immediate neighbourhood of the vessels, or in the subserous and neighbouring areolar tissue in which they ramify; and by the filling and distention of the meshes of this net-work, it gradually communicates its own appearances to the surrounding tissue generally.

The next stage is constituted by the appearance of the products of inflammation on the inner or free surface of the membrane, or the *effusion* of a plastic fluid into their cavity.

This effusion is at first a clear transparent fluid, of a tolerably limpid consistence. It is true that we are rarely able to verify this transparency in the exsudation of the larger serous membranes; but the condition of the blood plasma from which it is derived, and the similar appearance which is visible in the case of fluid effused into the inflamed anterior chamber of the eye, together leave no doubt of the fact.

In a space of time which is a very short one, this uniformly fluid state usually gives place to a greater or less opacity and solidification; and in this, the earliest stage in which the effusion is generally recognized, it offers the appearance of a milky semifluid substance, which either forms the whole of its mass, or is mixed with a variable quantity of serum, from which it has thus already begun to separate.

The *composition* of this effused fluid exhibits

great variety in different cases. The following table is an average of five analyses by Quevenne, Scherer, and Vögel, which is compared with the liquor sanguinis of healthy blood, as analysed by Lecanu. This important comparative method of regarding these fluids is due to Vögel, in whose valuable work these analyses are given at length.

	Liquor Sanguinis.	Fibrinous Effusion.
Water - - -	906	934·936
Fibrine - - -	3·4	·984
Albumen - -	77	51·88
Extractive - -	3	12·2
Fat - - -	3	
Salts - - -	8	
The composition of	1000·4	1000·

A comparison of the composition of this fluid with that of the serous effusion which was previously described, not only exhibits the addition of a new constituent, fibrine, but it shows the quantity of albumen to be increased in an important degree; it being, on the average, nearly trebled. Contrasting it with the normal liquor sanguinis, it is seen to possess a considerable proportion of its albumen and fibrine, although less than this fluid itself contains. And it is important to notice, that the former of these two constituents is not only present in larger quantity than the latter, as might be expected from its very different amount in the parent fluid, but in a much greater proportion of its respective quantity, *i. e.* that only two-sevenths of the fibrine of the liquor sanguinis appears in the inflammatory exsudation, while five-sevenths of its albumen is present. And in all probability, were the diseased liquor sanguinis of the same subjects the object of comparison, its increased quantity of fibrine would render the disproportionately small transudation of this constituent a still smaller one. Although the number of analyses from which the average is taken will allow little stress to be laid upon these facts, yet they have seemed to deserve especial notice, as having some bearing upon a question which is of the greatest importance to pathology, and which cannot yet be considered as settled, viz. "What is the relation of fibrine to the process of organization?"

The further progress of the exsudation arranges the plastic or fibrinous constituent as a more complete coagulum, which is in contact with the inner surface of the serous membrane. The colour of this portion of the exsudation is yellowish, or sometimes reddish from mixed blood; its thickness varies from that of a scarcely perceptible deposit to one of half an inch or more in thickness. The uniformity with which it covers the interior of the membrane is also subject to great differences; sometimes it is arranged as a stratum of tolerably equal thickness over the whole or a greater part of its extent, at others it is limited to the formation of raised points or patches which here and there stud its surface. These conditions apparently indicate a corresponding diffusion or limitation of the inflammation. In like manner, the state of surface of this stratum is liable to great differences, being sometimes level and comparatively smooth, while in other instances it offers every conceivable degree of roughness, from a trifling irregularity of surface to those long, large, and shaggy processes which are so often seen in acute pericarditis, and which have been well compared to the villi of an ox's tongue. Considerable difference of opinion prevails as to the exact mode in which this curious state is produced: thus some imagine it to be the result of the mutual movements of the visceral and parietal layers of the membrane; or that, in separating from each other, they draw out a thread of the viscid and coagulating paste, until it breaks, and thus leaves a projecting process attached to each of these surfaces. But the fact, that an elongation very similar to that of those processes is seen in solitary warty deposits on the valves of the heart, in situations where no such physical causes as this can be supposed to obtain, renders this explanation more than doubtful; and, on the whole, the interpretation of Vögel seems much more probable, that they result from a want of uniformity of the effusion in the first instance forming small scattered patches of lymph, on and around which, as around foreign bodies, the subsequent continuous effusion tends to deposit itself.

The first layer of fibrine thus deposited on the inner surface of the membrane forms, if it is complete, a kind of sac, in which the more serous part of the exsudation is included. But this liquid part generally contains a considerable further portion of the fibrinous element; and the resulting phenomena appear to depend in some measure on its amount. Thus, if the exsudation be almost wholly of plastic material, large irregular masses of fibrine are found in the cavity of the membrane; the serous fluid being only in sufficient quantity to moisten these loose coagula. If the serum be superabundant, the fibrine may remain almost or entirely dissolved in it; or may only be visible as a slight disturbance of its transparency, imparting to it a white colour, or forming a few scattered flakes which float hither and thither in the fluid. A medium between these two extremes is perhaps more common, in which the plastic element coagulates in a loose irregular kind of net-work, the meshes of which enclose the serum. And with this more general precipitation there is usually a special deposit upon the peripheric or oldest layer before mentioned, which imitates its irregular or shaggy form. But as this process of coagulation is often a very slow one, the extent of lamination is by no means limited to these two layers; five, ten, or twenty thin strata often appearing to be laid down from the fluid, one after another. In all these cases, the denser and stronger layer, in contact with the surface of the serous membrane, is the original plasma, the first which was deposited, and the earliest to be organized. Rarely the completeness of this coagulation leaves the serous part entirely

devoid of fibrine, and, in respect of composition, closely resembling some of the dropsical fluids previously described.

Organization of the effusion. — In some very few instances, in which the exsudation is only in a limited quantity, absorption occurs prior to the deposit of the fibrinous portion; but after this change has once occurred, and the fluid has been separated into a serous and solid portion, the former only is susceptible of removal, the latter or fibrinous constituent being either absolutely incapable of absorption, or, what is perhaps more probable, being removed so slowly as to be replaced by the organization of new tissues long before its withdrawal is completed. When the quantity of fibrine is small, organization is on the whole both less frequent and rapid. Still it may occur; and even where this substance is retained in solution, the fluid containing it is susceptible of this change.

But although the products of inflammation generally progress towards organization, yet the steps and results of this further development differ very widely from each other.

In the majority of these effusions, one of two processes occurs. In one class of cases, the free surfaces of the membrane are glued together by the coagulable lymph effused upon them; and this cementing substance is either itself converted into a permanent structure which obliterates the cavity, or it forms a nidus or stroma in which the structure is developed. In another set of cases, the plasma experiences a rapid development into a number of cells, floating in a thin fluid. These are termed the adhesive and suppurative forms of inflammation respectively; or sometimes, with perhaps less correctness, the "terminations" of this process.

In some instances, however, a process similar to the first of these takes place independently of adhesion. Sometimes, the plastic layer on the inner aspect of a serous membrane experiences a transition into a structure which resembles areolar tissue, and presents an irregular or shaggy surface, like the fibrine for which it is substituted. In other instances, a thinner layer, with a more regular surface, is formed, and clothes the normal structure with a new serous or fibro-serous membrane, which can readily be peeled off from the subjacent tissue. This layer is rarely of uniform thickness, and when limited to small isolated patches forms the "white spots" which are so frequently seen in the pericardium. In these instances, the effusion is evidently in very small amount, and probably consists almost wholly of the plastic materials of the blood, with very little accompanying serum.

Another class of cases may be mentioned here which, in respect of the absence of adhesion, are somewhat similar to this condition. They differ from it, however, in the fact of their presenting a large quantity of a serous or little fibrinated fluid, and in the very slow organization of their solid matter, which, in some instances, advances so little in a considerable lapse of time, that we might almost doubt the occurrence of any further developement. In these instances, the small amount of plastic material present is irregularly deposited here and there in the shape of small granules of fibrine which are scattered over the surface of the serous membrane. This condition frequently occurs in the peritoneum, and has been called "tubercular peritonitis." It offers, however, such wide distinctions from the really tuberculous inflammation, that it is difficult to imagine that the term was ever used to express more than the shape of the deposit; and in order to avoid the confusion caused by designating two such different diseases with one name, Mr. Simon has suggested that of "granular peritonitis," a term which avoids this objection, but equally indicates the peculiar form which the fibrine exhibits.

When the plastic material has been mainly deposited on the walls of the cavity, and has included a considerable quantity of serum in its interior, an absorption of this fluid necessarily precedes the contact and adhesion of the opposed surfaces. But in the more diffuse and irregular coagulation previously alluded to, in which the serous portion occupied the meshes or interstices of the fibrinous net-work, the latter may become organized, and may thus form cyst-like cavities, which are permanently filled with this fluid.

In most instances, the serum having been absorbed, and the walls of the cavity having been united by coagulable lymph, the latter becomes slowly organized into a substance which resembles areolar tissue, but contains comparatively little of the yellow fibrous element. Cotemporaneously with this change, vessels are developed in the mass by a series of processes, which, in all probability, closely approximate to those of their formation in the embryo. The resulting structure occupying what was previously the cavity of the serous membrane, effectually prevents the repetition of such an effusion; although there is no reason to believe that it confers an abstract immunity as respects the inflammatory process.

The *suppurative inflammation* of the serous membranes frequently offers, in its symptoms or causes, few differences from the adhesive variety; but the formation of pus is sometimes discoverable at so early a stage of the disorder, as to render it doubtful how far it may not be considered, not so much a mere form or termination of the disease, but an inflammation *sui generis*. Where pus has been received into the bloodvessels, and circulated with their contents, large collections of this fluid are sometimes seen in these tissues: these are, however, to be distinguished from the suppuration which occurs primarily as the result of an inflammatory process. In the latter case, the cavity of the inflamed serous membrane is usually lined by a soft, irregular, and membraniform exsudation, resembling the wall of an abscess, to which the altered tissue may, under these circumstances, be fairly com-

pared. The appearances of the pus present the varieties met with in this fluid generally.

In the most favourable cases, the fluid rapidly diminishes in quantity; and the pus-cells, which are incapable of further organization, disappear, the substances which compose them being, in all probability, absorbed subsequently to the breaking up of their structure; while the remaining parts of the exsudation become organized together with the adhering walls of the cavity, and result in the complete obliteration of the serous structure.

In other instances, the suppurative process takes a more unfavourable course; the pus assumes a sanious appearance and a very offensive smell; and, finally, after ulceration or sloughing of the serous membrane, is discharged through the opening into the cavity of the viscus, or into a neighbouring serous membrane, or on the surface of the body.

Sometimes this process appears to be modified by the occurrence of a less complete absorption. The pus, deprived of certain of its constituents, is slowly transformed into a mortar-like mass, lining the membranous wall by which it appears to be secreted. The sandy or gritty consistence of this substance shows that it contains chiefly the inorganic constituents of the exsudation; and sometimes the fluid, gradually thickening, passes into a cheesy pultaceous mass, and thence, by long duration, into a cretaceous substance, resembling that into which tubercle often degenerates.

The so-called *chronic inflammation* presents no differences which can be called essential; most of them chiefly referring to the duration and intensity of the process, rather than to any peculiarities in its nature and appearances. For instance, if the general symptoms are less prominent than usual, and the disease progresses slowly, with frequent remissions and exacerbations, it is called "chronic." So, also, the same name would be applied to a case which, originally "acute" in the intensity of its symptoms, and the rapidity of its progress, had overpassed the violence of the first attack; the effusion remaining with diminished constitutional disturbance. Or a recurrence of the inflammation, pouring forth a new effusion in and within the already dense and hardened layer of a previous exsudation, is called chronic. In such a relapse, the unorganized exsudation has been said to be the seat of the secondary inflammation; but it may be questioned how far the inflammatory process can occur in a tissue which is as yet unprovided with vessels: and even were the absence of these as complete as it seems to be, the inflammation of the lymph would scarcely be a necessary supposition, since it would be difficult to deny the possibility of a physical transudation of fluid, derived from the nearest vascular surface, or that of the original membrane.

Besides these divisions of inflammation according to its duration and results, there are others, in which the process is complicated by its occurrence in connection with other diseases, or by its dependence upon some specific cause. Amongst these the "hæmorrhagic" effusion, first recognised by Lænnec, holds a very conspicuous place. In this disorder the inflammatory exsudation is mingled with more or less blood, which communicates its colour and appearances to the whole mass, in a degree varying with the quantity in which it is present. By longer duration, it separates into two parts: a peripheric layer of whitish or slightly-coloured lymph, which covers the serous surface; and a fluid which contains the greater part of the blood corpuscles and serum, and is included in the cavity formed by the plastic layer. This liquid portion is only capable of a very slow absorption, and prior to this event it passes through many gradations of colour and appearance. Generally, it slowly loses its red colour; but in the case of the hæmorrhagic inflammations of the peritoneum, it very frequently becomes darker, and, finally, almost black; a change which seems due to the action of the intestinal gases. This conjunction of inflammation and hæmorrhage occurs in many diseases, but with the greatest frequency in tubercular cachexia, in fevers, and in other exanthemata. In all these disorders, the mass of the blood is greatly affected, and in many of them sufficiently so to exhibit marked deviation from the composition and properties of the healthy fluid. And in addition to these, the general conditions of its occurrence, Rokitansky * points out a local circumstance which greatly favours its access; viz. the previous existence of a plasma, in which organization is commencing. And he refers this aptitude for hæmorrhage to the probable state of its vascular apparatus, which, in this early stage of its development, offers simultaneously the greatest delicacy in the texture of its walls, and a deficiency of anastomosis with the neighbouring vessels; two conditions which would respectively diminish its capacity of resistance to any distensive force, and increase the amount and duration of this distension. And in illustration of this his opinion, it may be pointed out, that a granulating surface on the exterior of the body seems closely to imitate these local conditions; while the resulting hæmorrhage, often traceable to the congestion mechanically producible by posture, often depending on exciting causes of a more recondite nature, affords a parallel to some of the effusions noticed above.

The *events of inflammation* are mainly included in the preceding sketch of the effusion which constitutes its most important feature: in this manner adhesion, suppuration, ulceration, and more rarely sloughing, occur. But they also happen, though with less frequency, as secondary affections of the serous membranes, in connection with diseases of the viscera or cavities which they cover. Thus, a morbid process in the immediate neighbourhood of a serous membrane frequently causes

* Handbuch der Pathologischen Anatomie, Band ii. S. 28.

a slight *effusion*, which is followed by an adhesion of its visceral and parietal layers ; an effect which is usually attributed to an "irritation" of the part by the disease. And as this process generally precedes any similar extension of *ulceration* to these membranes, it has the salutary result of sealing up their interior, and thus of preventing what would otherwise be a serious or even fatal effusion into their cavity. Their destruction by the communication of an ulcerative process in their immediate proximity may be called by the same name ; but it often more resembles *sloughing* in the rapidity of its course, and in the imperfect absorption of the broken down textures. So also where *softening* of these tissues happens, it almost invariably depends upon an action which primarily affects the subjacent viscera, and gradually implicates their serous covering.

Tubercle. — The deposit of this morbid product in the cavity of a serous membrane constitutes but a part of the general tubercular cachexia; and in the majority of instances, it only occurs after the disease has been localised in some other organ; often, indeed, after it has already implicated the respiratory apparatus. And even in those cases in which its symptoms precede other manifestations of the disease, it appears extremely probable that the lymphatic glands of the immediate neighbourhood have been the original seat of the deposit, and that from thence it has, as it were, extended to the particular serous membrane.

Occasionally, the tubercular matter is deposited in and amongst the effused products of inflammation, so that the two processes appear to merge into each other, with a similar mingling of their products. This occurrence of tubercle in connection with inflammatory exsudation has been minutely described by Rokitansky, who considers that a complete metamorphosis of the latter substance into the former does, in some instances, obtain. But from the difficulty of procuring direct evidence upon this point, *i. e.* of examining different portions of the same effusion at different periods of its duration, one may be allowed to doubt whether such a transmutation, or even a substitution, is really effected.

Generally speaking, the coexisting inflammation plays a more subordinate part. Where the tubercular matter is thus comparatively uncomplicated, it occurs in the form of greyish semi-transparent granulations, of about the size of a millet-seed, or rather larger. The situation of these is usually on the inner surface of the membrane, which they render irregular by their presence, so that on removing a tubercle (which is easily peeled off from the subjacent texture), a depression of a size which corresponds to it is exposed, in which the serous membrane has lost its smooth and shining character, and has become dull and somewhat opaque. Besides this, which is the ordinary form of tubercle in these textures, other and smaller varieties often occur : and where a large quantity of the deposit is present, more or less exsudation unites the whole into a layer ; in which, however, the granularity of their developement can still be discerned. Usually, a certain amount of serous fluid is also present, the quantity of which has some relation to the extent of the disease. In the peritoneum, however, its quantity is for the most part insignificant ; and the cavity of the serous membrane is completely filled by a thick and solid, yet granular mass of tubercle, by which the viscera and abdominal parieties are completely matted together. Sometimes, but rarely, the texture of the serous membrane itself, or the subserous areolar tissue, becomes the seat of the deposit ; in these cases its quantity is small. The after-changes of tubercle in these tissues may lead to suppuration and ulceration, or to a slow absorption of the organic constituents of the mass, and a cretification of the remainder ; but in the greater number of cases, the patient dies of the general disease without either of these events having happened.

Cancer of these tissues is comparatively rare : and of those instances which do occur, many are scarcely affections of the serous membranes themselves, but ought rather to be considered as secondary, and dependent on a mere local proximity. Thus, a neighbouring cancerous tumour, by the progress of its growth, comes into contact with a serous membrane, and, as its size increases, gradually implicates this structure in its own diseased mass. Sometimes they are primarily attacked; yet even here, other organs generally suffer at the same time, and either complicate or mask the local disease.

The carcinomatous deposits themselves offer few special peculiarities of appearance. The harder or scirrhous forms are seldom seen ; the softer varieties, viz. the gelatiniform or areolar, the medullary, and the melanotic, being those to which they are most liable. For a description of these the reader is referred to the article ADVENTITIOUS PRODUCTS.

Ossification of the serous membranes is also infrequent. Like the same process elsewhere, the deposit of bony matter never occurs alone, but is a very slow change, which appears to require the existence of a previous tissue. Hence, it is limited to two forms, neither of which primarily affect the cell-growing membrane. In the first, the fibrinous exsudation of a preceding inflammation is gradually transformed into ossific matter. In this case, the shape of the deposit is rough and irregular, and sometimes it forms a kind of nucleus, which occupies the centre of the tough fibrous mass. Its appearances sometimes approximate to those of the cretification before alluded to, as possibly do the several processes which form these substances. In the second variety, the subserous and neighbouring areolar tissue is occupied by the deposit ; but here also

a fibrous or fibro-cartilaginous thickening, which is itself the developement of an exsudation, is probably the immediate seat of the change; and a variable quantity of this morbid tissue is generally seen around and upon the bony matter. The shape which, under these circumstances, it assumes, is somewhat more regular than that of the preceding variety, it being often flattened and extended in thin plates, the roughly tuberculated surface of which is, for the most part, parallel with the surface of the membrane.

The pleura is the most frequent site of these ossifications, as it is also of the adhesions in which they mainly occur: but they are also found in the subarachnoid tissue and pia mater; and, more rarely, in the peritoneum and the synovial sheaths of the tendons.

Cysts are often found in these membranes, but their great differences of nature and causes claim a longer notice than can be accorded in this brief sketch. Three chief varieties may be distinguished. One of these is inhabited by parasitic animals, as the echinococcus. These are usually found in great numbers, and may occur in any of the serous membranes, although the peritoneum is their most frequent locality, probably from its proximity to the intestine by which they are introduced into the body. Sometimes they occupy the cavity of the membrane, and are in contact with its interior by a slightly flattened part of their surface; in other instances, they project into the cavity, carrying the membrane before them; and at least one layer of their wall is formed by lymph derived from the neighbouring vessels. Another form is not recognised as parasitic, but in the present state of our knowledge might rather be described as a gigantic cell, which often includes a vast progeny of smaller ones. The whitish powder which some of these contain, may frequently be seen to be completely composed of small cells, which are devoid of a nucleus, of uniform size and spherical shape, and exhibit a clear sharp outline. These characters alone would, perhaps, indicate their merely cellular nature, as above stated; but the general appearance of these contained globules is suspiciously like the ova of entozoa. In other cases, the included cell again includes a smaller one, and this yet another, so as to form a series of concentric hollow spheres; an arrangement which has named them as the pill-box hydatid. In their general appearances, they closely resemble the preceding variety. The fluid contents of both are limpid and transparent, and are composed of water, with blood salts (chiefly chloride of sodium), and an exceedingly small quantity of albumen. Yet the effusion of this apparently harmless fluid into the serous cavities gives rise to an inflammation of the greatest violence and fatality. In a third class of cases, the cysts are usually in much fewer numbers than the preceding: they occur for the most part in the neighbourhood of the female reproductive organs; and this their situation, together with their contents, which often consist of teeth, hair, bone, fat, and other products of an abortive development, sufficiently indicate a relation to the generative process. The fluids which they contain are albuminous, often sufficiently so to possess a glairy consistence. They exist within the cavity of the serous membrane, or in its texture, indifferently; when developed in or beneath the subserous areolar tissue their gradual enlargement causes them to reach the free surface of the membrane, and then to dilate and extend this tissue before them, until finally the cyst, still covered by the serous layer, hangs freely in the cavity by a more or less elongated peduncle, which is formed by this covering where it becomes continuous with the rest of the serous membrane.

The *subserous areolar tissue* has been mentioned as implicated in most of these diseases; but other morbid conditions are not wanting, in which it appears to be affected without the essential participation of the remainder of the tissue. Such are the little masses of fat which are occasionally found projecting into the serous cavities; they are covered by the smooth and apparently healthy membrane, and their form is generally pedunculated, or sometimes ramified and arborescent. The development of this shape corresponds with that of the subserous cysts just mentioned. The fibrinous Pacchionian bodies of the cerebral meninges have been similarly explained as arising from the pia mater, and gradually invested with a layer of arachnoid which becomes converted into a peduncle, the rupture of which leaves them adhering to the dura mater, or even projecting into the longitudinal sinus.

Loose cartilages. — The cavities of the serous and synovial membranes sometimes contain morbid products in the shape of certain free or unattached substances, which, from their usual appearance and consistence, are best known as "loose cartilages." The most frequent situation of these bodies is in the knee-joint, and next to this, in the synovial sheaths of the flexors and extensors of the hand or foot; but they are not uncommonly found in the subcutaneous bursæ over the patella, trochanter, or acromion. More rarely they are seen in connection with the serous membranes; for instance, in the tunica vaginalis testis, or in hernial sacs. They may also exist in the diarthrodial species of false joints.

Their appearances offer great variety in different cases. In some instances, as often happens in the knee-joint, only one, or perchance two such bodies are present. Here they are of considerable size, attaining the magnitude of a large bean or almond; their shape is a more or less flattened oval, and their surface is smooth and slippery. Their consistence is firm and elastic, their appearance whitish and cartilaginous, their substance uniform and structureless.

When comparatively recent, or of only a

few weeks' or months' standing, they may vary somewhat from this description by the possession of a rough surface on one side, which indicates the seat of their previous attachment to one of the bones of the leg. The observations of Cruveilhier * have furnished us with a knowledge of the stage which, at least in some instances, immediately precedes this condition. He has shown that, in some cases, the development of these bodies occurs in the subserous or rather subsynovial tissue; that their enlargement carries forward the synovial membrane; and that a peduncle is thus formed, the rupture of which sets them free, in the articular cavity.

There are other cases which possibly represent a different class, and which are distinguished from these by the characteristics of the greater number, lesser size, and, for the most part, much softer consistence of these bodies. Their general features have long been known to anatomists, and recently the minute descriptions of Bidder† and Hyrtl ‡ have added important, though apparently conflicting, details concerning them.

In the case which Bidder has narrated, the morbid product was removed from the knee-joint during the life of the patient, so that the appearances of the synovial membrane are necessarily wanting. The mass consisted of granules, the shape of which was always a flattened oval; and their size offered a similar uniformity, the length of the oval being about one-eighth of an inch, and this about double and treble its width and depth respectively. Their surface was smooth and shining, their colour yellowish-white, and a viscid fluid in sparing quantity (probably synovia) united them into small clumps or masses. In consistence, they were softish, yet highly elastic, resuming their original size and shape immediately after the removal of a flattening pressure. A microscopic examination showed them to consist of an uniform substance, and to be entirely devoid of all traces of organization. Their chemical reaction was that of an albuminous solid; — viz. they were unchanged by water or ether, were shrunken by the application of alcohol, and were swelled out into a transparent mass by acetic acid. The substances described by Hyrtl differed in many important respects from the preceding granules. The synovial sheath of the flexor tendons was distended, so as to form a protuberance above and below the annular ligament of the wrist. Pressure on either of these swellings alternately gave rise to a predominance of the other one, and was attended by a kind of crepitating sound. On laying open the sheath, its interior was found to be occupied by upwards of a hundred small bodies, which in their colour and general appearance seem to have greatly resembled those described above; but their consistence appears to have been softer, their size less uniform, varying from that of a hempseed to a lemon-pip, and their flattened shape was, in most instances, altered by the possession of an elongated extremity, although others were more globular. The sac itself exhibited very interesting appearances. The tendons, where they passed through it, were greatly diminished in bulk. The parietal portion of the sac appeared to consist of two layers, a serous and a fibrous, the latter of which was dense. (Probably this appearance was partly due to a condensation of the neighbouring areolar tissue by pressure into a membranous form, similar to that seen in the sac of an aneurism.) The synovial membrane, where it covered the tendons, was looser than natural, and had lost its smoothness and polish, while in many places it had acquired a villous appearance. In the subserous areolar tissue, little knots were seen, many of which projected into the sac, carrying before them a covering of the serous membrane; others of them had rather a constricted neck; and, finally, in others this constriction had increased so as to form a peduncle of little more than the thickness of a hair. The severance of this connection brings these bodies to the same condition as the granules which were found free in the cavity; but the bulk of many of these was larger, while those yet in connection with the sac were uniformly of small size. This larger size of the unattached bodies was also noticed by Morgagni. The minute anatomy of both the free and attached substances was the same. Their surface was clothed with an epithelium of angular flattened cells, and their interior contained areolar tissue and fat, with a grumous coagulated substance. These two normal tissues, however, were not in a healthy state; the fat cells were wrinkled, their contents half solidified, almost opaque, and of a sordid yellow colour; the areolar tissue was alike destitute of regular arrangement and of its ordinary wavy lines; while with all this was mingled much amorphous débris.

Concerning the mode of formation of these substances considerable differences of opinion have prevailed, which may justify a slight notice in this place.

The descriptions of Cruveilhier, Hyrtl, and others, leave no doubt as to what is the process of their development in at least a large proportion of instances. These exhibit them as affections of the subserous, or rather subsynovial areolar tissue; while the circumstances under which they are found, such as the arrangement of the deposit in small masses, which are plentifully scattered over a large surface, the aged and debilitated constitutions in which they are chiefly present, &c., indicate with tolerable clearness that they are the result of disease, as contradistinguished from external violence.

But it may be doubted whether this expla-

* Patholog. Anat. ii. 2. p. 211.

† Henle und Pfeuffer's Zeitschrift, 1845, Band iii. Ueber Entstehung fester Körper in den von Synovialhaüten gebildeten Höhlen.

‡ Oesterreiche Medizinische Jahrbucher, Bd. xxxix. S. 261. Anatomische Untersuchung einer sogenannter Hydatiden Geschwulst des Schleimbeutels der Beugesehnen am Carpus.

nation will apply to these unattached bodies universally: it seems more probable that amongst these substances are included some which have not only a different origin, but also a different relation to the synovial membranes.

Thus, it was imagined by Hunter* that "the loose cartilages usually found in the knee-joint originated from a deposit of coagulated blood upon the end of one of the bones, which had acquired the nature of cartilage, and had afterwards been separated." He conjectured that their pedunculated shape during the period of their attachment depended on the movements to which such deposits were liable during their soft condition; and in confirmation of this he adduces an instance in which some blood effused in the abdominal cavity acquired a peduncle half an inch in length before it lost its red colour, and, when washed, exactly resembled a pendulous tumor. And as to the possibility of the transformation of such an effusion into a cartilaginous-looking substance, reference is made to "an examination of joints which had been violently strained or otherwise injured, where the patients had died at different periods after the accident. In some of these there were small projecting parts, preternaturally formed, as hard as cartilage, and so situated as to be readily knocked off by any sudden or violent motion of the joint." The frequent connection of this variety of loose cartilage with external violence has long been known, and in some of these cases symptoms of local inflammation mark the period of their formation; while, after a certain interval, the accident of their separation occurs, attended by the ordinary effects on the movements of the joint.

These facts, however, while they afford a great probability that external violence may operate as a cause of these growths, by giving rise to an effusion, which in some instances consists, it is most likely, of blood; yet they do not exhibit the relation of this effusion to the synovial membrane. But it may be conjectured from the situation and arrangement of the vessels, that a sudden hemorrhage, to any perceptible amount, would necessarily imply the rupture of this delicate tissue, and the consequent presence of the effusion in its cavity; while a smaller or slower process would carry the membrane before it; or, in other words, that the presence or absence of the serous covering would chiefly depend on mechanical conditions; and that, in either case, the result would be little affected.

Indeed, the synovial membrane itself cannot be considered immediately essential to the formation of these substances; another vascular surface may be substituted, the result continuing the same. Thus, Sir Everard Home† mentions a case in which thirty or forty such substances were found loose in the cavity of a false joint, having apparently been mechanically broken off from a number of projecting portions of cartilage, which studded the broken ends of the bones, leaving exposed interstices. Although slight variations in the size and shape of these substances, and more considerable differences of their consistence, are spoken of, yet their description essentially coincides with that of the preceding bodies examined by Bidder.

Taken altogether, these facts seem to indicate that the unattached substances which are found in these tissues include the products of very different pathological conditions and processes. They appear to show that morbid deposits beneath the synovial membrane, effusions the result of violence, and either occurring beneath it, or by mechanical extension in its cavity, and finally, irregularly formed cartilage, may all, under certain circumstances, give rise to the production of these substances.*

The conditions essential to their transformation seem to be of a twofold nature, mechanical and physiological; exposure to pressure and movement, and the presence of a synovial fluid. It is doubtful how far the acquisition of the peduncle noticed in some, may depend on the joint influence of their extensibility, and the mechanical violence which must be exerted on such isolated prominences. But the separation, whether of these, or of those seen in the false joint, is obviously the direct result of violence. Pressure seems an important condition, so much so, that a close relation may probably be traced between its amount and the degree in which they have assumed the cartilaginous form and consistence; the synovial sheath, the knee-joint, and the false joint appear to present gradations in both these respects. And as to the operation of the synovial fluid, similar probabilities may be deduced. The mere permanence of these bodies seems to point out that they possess some kind of nutrition; and the increased bulk noticed by Hyrtl in the unattached as compared with the attached substances, would still further necessitate such a supposition; their structure sufficiently denying the suggestion that the increase is due to the union of two or more. And in the case described by Hyrtl, the structure of these bodies seems to show that the results of a previous organization are not exempt from this transforming process, but may undergo a degeneration into a cartilaginous substance. And in the absence of any inherent or chemical capacity of their contents for such a change, this would yet more require the supposition of an agent of nutrition, which should supply the materials, if it did

* Transactions of a Society for the Improvement of Medical and Surgical Knowledge, vol. i. p. 231.

† Loc. cit.

* I may, perhaps, mention, that since writing the above, I believe myself to have verified the conversion of bone into these structures. The change was partial, and the vessels seem the immediate agents of the process, since not only did a superficial stratum of cartilage occupy the whole surface of a pedunculated and cartilaginous structure, but a layer of nearly equal thickness surrounded the vessel in each Haversian canal. See Medical Gazette of Dec. 8. 1848.

not effect the metamorphosis. While the complete isolation of these bodies from the vessels which are the immediate channels of nutrition, leaves only one supposition, viz., that the synovial fluid is the pabulum from which they derive the materials essential to their permanence, growth, or alteration. The composition of this fluid as compared with their own, perhaps sufficiently warrants this conclusion.

Other conjectures as to the mode of their development are offered by Bidder, such as the possible precipitation of synovia around an epithelial cell, the gigantic development of a cell, or, what much approximates to this, their hydatid nature.

In certain abnormal conditions of the articular cartilages, peculiar appearances of the synovial membranes are seen, although it is somewhat doubtful how far they can be regarded as essentially morbid.

Thus, for example, in the ulceration of diarthrodial cartilages, it appears probable, that the removal of their substance is chiefly accomplished by the synovial membranes. Cruveilhier * narrates a case in which purulent fungosities of this tissue replaced the destroyed cartilages of the ankle-joint; and the general connection of hypertrophy of the membrane with ulceration of the cartilage has long been known. More recently, Mr. Goodsir's † investigations have thrown much additional light on this subject. He has shown that the preternaturally active growth of the cartilage, and the similarly rapid change of its properties and appearances, are to be regarded as inherent in this tissue itself; that where the destruction of its substance occurs at its margin, or in the immediate neighbourhood of the vessels, a fungous enlargement or extension of these accurately fits into the eroded part; but that in the ulceration of the centre of the cartilaginous lamella, such a physical adaptation is absent. From these circumstances it seems probable that the absorption which is accomplished in the former case by the local enlargement, is in the latter shared by the vessels of the synovial membrane generally.

A somewhat similar, but much less prominent affection of vascularity has been described by Dr. Todd ‡ in the porcelain-like condition of these cartilages, which often obtains in the chronic gout of the aged. The highly injected vessels of the synovial membrane were covered by a whitish powder, which was doubtless a frictional detritus of the diseased cartilage. How far this congestive state is connected with the absorption of this powder, is unknown.

(*William Brinton.*)

SESAMOID BONES. By this name are designated the small bones met with in the neighbourhood of certain joints, generally in the tendons of the adjacent muscles. They owe their name (σησαμη ειδος) to the figure which they usually possess, resembling that of an Indian grain called sesame. But the present application of the term regards the character of their situation in the course of a tendon, rather than their form; for instance, the patella is often said to be a sesamoid bone, not because it resembles sesame, but because it is placed in the tendon of the extensor cruris muscles. This character of their situation in the course of tendons constitutes their chief point of interest; it is in this that they are peculiar, and different from other bones.

In the human subject these bones are usually met with only on the palmar aspect of the metacarpo-phalangeal joint of the thumb and the homologically corresponding part of the great toe, in both of which situations there are usually two. These are not constantly present, and, according to Cloquet, are not met with in children, owing, probably, to their becoming ossified late, though in young Ruminants and Solipeds, as well as in other animals, I have found their ossification as far advanced as it was in the other bones. They are more frequently absent in the hand than in the foot, and in females than in males. The long flexor tendon of the thumb or great toe passes between them, and the two are bound together above and below it by dense fibrous tissue, so that they assist in forming its sheath.

The sesamoid bones of the thumb are very small — usually not bigger than the half of a large pea. They have a somewhat oval outline, are convex on their palmar, and slightly concave on their dorsal aspect, which is articular, and covered with cartilage. They articulate with the head of the metacarpal bone. Those of the great toe are each as large as a horse bean, of a long oval outline, convex on the plantar aspect, and presenting a concave cartilage-covered surface to the head of the metatarsal bone, to which they are adapted.

The little pieces of bone, situated and shaped as above, are enclosed in the tendons of the short flexor muscle of the thumb or great toe, the fibres of which have the following relation to them: — Some of the tendinous fibres pass over them, and some on each side, whilst their articular cartilage, as I have verified by microscopic examination, becomes mixed with tendinous fibres, passing on their arthrodial aspect, as it approaches the bone. The greater part of the tendon, however, is inserted into their proximal, and arises again, so to speak, from their distal end. The arthrodial surface of their articular cartilage forms part of the synovial surface of the subjacent metacarpo-phalangeal joint, and they are held in their place by the strong fibrous tissue of the common synovial capsule.

Structure. — The sesamoid bones consist of finely cancellated osseous tissue, enclosed in a shell of denser bone. The main direction of the osseous columns that surround the cancelli is longitudinal, but they intercommunicate in all directions. These columns are much

* Archives Générales de Médecine, vol. iv. p. 161.

† Anatomical and Pathological Observations.

‡ Medical Gazette, 1847.

stouter towards the external part than towards the inner or that which is in contact with the long flexor tendon.

A *microscopic* examination of sections, taken in the three cardinal directions, shows that they possess much the same minute structure as other similarly shaped bones. The lacunæ are large and expanded*, the canaliculi distributed arborescently, except a few in the immediate neighbourhood of the cancelli and Haversian canals, where they have the straight and parallel arrangement met with in the shafts of the long bones. The Haversian canals are but few in number, their place being plentifully supplied by the numerous cancelli. The dense surrounding shell is stratified parallel to the surface, very markedly so on the articular aspect, where it is thickest. At the points where tendinous fibres are attached, it appears to be laminated at right angles to the strata and the surface, as though the fibres of the tendon were received between the plaitings of osseous laminæ, or conversely as though the ossification had extended up in laminæ between the tendinous fibres. The lacunæ that occur in this crust are mostly large and clumsy, elongated and directed vertically or obliquely towards the surface, particularly the articular surface, and all of them destitute of canaliculi; a condition met with in the superficial osseous crust of other articular surfaces, and points of attachment of tendons, especially in old subjects. — It is probably the form of osseous tissue that results from the ossification of permanent cartilage or white fibrous tissue; but my researches, in order to ascertain this point, have not been sufficiently extensive.

Developement (examined in young Ruminants). — A small mass of temporary cartilage precedes the osseous condition of these little bones. This becomes ossified from a single central point in the manner of an epiphysis, as described at page 857. Vol. III. art. Osseous Tissue.

Disease and injury. — I am not aware that the diseases or accidents affecting the sesamoid bones have ever been noticed, unless the patella be considered a sesamoid bone, which, indeed, it is in structure, by situation in a tendon, and in function. This bone comports itself in disease just as other bones do (see Knee Joint, Abnormal Anatomy). When fractured transversely, it presents the peculiarity of uniting, by white fibrous tissue, instead of by bone. I cannot regard this non-union by osseous tissue as resulting from any deficiency of nutritive or reparative power in the patella, for new fibrous tissue is *always*, and when the fracture is longitudinal, even new bone is *usually*, formed; nor from want of apposition, for in many ununited specimens the apposition is very perfect. Osseous union, as a result of reparative inflammation, never occurs in situations where the new material of repair is not subjected to pressure, as in the skull, acromion, olecranon, heel, — a hole made in the scapula does not become filled up with bone. I therefore regard the non-union by bone of transverse fracture of the patella as due to the absence of that stimulus (pressure) which I conceive to be necessary in order to determine the reparative material to assume the osseous form; whilst I attribute the union by ligament to the presence of the stimulus (tension) which I regard as necessary, in order to direct the metamorphosis of the adhesive lymph, or rather the mass of new corpuscles or cells, which is formed for the purpose of repair, soon after any accidental breach of continuity has been produced, towards the ligamentous form. These remarks would, of course, apply to transverse fractures of the sesamoid bones properly so called, in case such accidents ever occur.

Other sesamoid bones. — Sesamoid bones are occasionally met with in the human subject in other than the above-named situations. One is sometimes found at the distal joint of the thumb and great toe; two at the proximal joint of the forefinger and second toe; and one at the corresponding joint of the little finger and toe. There is pretty frequently one, or even two or three, in the heads of the gastrocnemius, just at the posterior part of each condyle of the femur. An ossification often takes place in the tendon of the peroneus longus, just where it doubles round the os cuboides; and a small bone is not unfrequently found in the tendon of the tibialis anticus, near its insertion into the scaphoid.

Comparative anatomy. — Sesamoid bones at the metacarpo-tarso-phalangeal joints exist in much greater number in the *quadruped mammalia* than in man; and they seem to be largest in animals that are digitigrade in their progression. I have not had an opportunity of scrutinizing their condition in the *Quadrumana*; none are preserved in the skeletons, and as the thumbs are somewhat rudimentary they are probably absent. In the *Seal*, a pair is situated on the metatarsal joints of both the hallux and the fifth toe, which greatly exceed the other toes in size; but there are none in the fin-like hands. They do not exist in the paddles of the *Cetacea* nor in the singularly modified extremities of the *Sloth*. In all, or nearly all, other *Mammalia* a pair occurs opposite every metacarpo- and metatarso-phalangeal joint. The two bones of the pairs are not unfrequently anchylosed together, as in the outer digit of the hand and foot of the *Elephant*. They are always situated in the course of the tendons of the interossei muscles. Often, however, as in *Ruminants*, their large size is enormously disproportioned to the small tendons on which they are placed, which, in this order with their muscles, are quite rudimentary, and the large sesamoid bones seem to be embedded in the sheath of the long flexor tendons. In *Birds* their place is occasionally supplied by large masses of fibro-cartilage. In Reptiles they are wanting.

The *patella* exists in all *placental Mammals*,

* See Vol. III. p. 850. *fig.* 452. art. Osseous Tissue.

but is absent in many *Marsupials*. In *Birds* it is usually, but not invariably, present; there are even sometimes two, one placed above another. In those aquatic birds which have the tuberosity of the tibia prolonged upwards as a large process, a patella is always found placed just behind it*, sometimes closely adapted to it, and extending beyond it so as apparently to form its summit.† No patella has been met with in any reptile.

Other sesamoid bones. — Opposite the plantar aspect of the distal joint of the fore and hind foot of *Solipedes*, there is a long supernumerary bone, called by farriers the shuttle bone, placed transversely. This, like the sesamoid bones above described, enters into the composition of the subjacent joint; a broad slip of the perforans tendon is inserted into its proximal side, whilst on the distal side a portion of the synovial capsule alone, and that not so strong as one would expect, attaches it to the ungual phalanx; the main part of the tendon passes over it to be inserted into the ungual phalanx, leaving a cavity lined by a synovial membrane between itself and the sesamoid bone in question. This bone reminds one of that which, as above mentioned, is occasionally found at the distal joint of the thumb and great toe in the human subject.

Small bones are found in one or both heads of the *gastrocnemius* in all Mammalia except *Man*, the *Seals*, *Pig*, and all *Ruminants* but *Cervus*, in which genus they are found, yet only in the external head of the muscle.

A sesamoid bone is met with in the insertion of the tendo Achillis of certain *Birds*, as the capercailzie ‡; and the tendons of the legs of birds are very commonly ossified, not, however, where they correspond to the joints.

Use. — Sesamoid bones serve much the same purpose as processes for the muscles that are inserted into them, without the inconvenience inseparable from a process, of giving an angular form to the joint. They also protect the long flexor tendons at points where perhaps they might be injured. But after all, taking into consideration all the facts related above, and many others that have presented themselves to me in the course of this inquiry, I cannot but believe, that some higher law than that of adaptation concurs in determining the presence, if not the size, of even these little bones.

(*S. R. Pittard.*)

SEVENTH PAIR OF NERVES (*Siebenter Nerv*, Germ.; *Le Septième Nerf*, Fr.). In laying the foundations of the natural sciences, few circumstances would seem to have occasioned more serious and permanent embarrassments than the immediate necessity of indicating the various new objects which they presented by specific names, and the difficulty of finding suitable ones. A nomenclature based upon their properties, would, perhaps, readily have suggested itself; but, generally speaking, the recognition of the object so greatly preceded the discovery of its properties, that this attempt was almost impossible. In the science of anatomy, this was especially the case; and a large proportion of the human structures were named, either according to their form, or, if this was not sufficiently defined, by their real or fancied resemblance to some previously known object; or failing this, by the proper names of their discoverers, however polysyllabic or uncouth they might happen to be.

In some one or other of these modes, the different parts of the complicated nervous centre received their various designations. But the cerebral nerves, although very similar to each other in the outward properties of their shape, size, and appearance, yet offered, by their fewness, a sufficient ground of distinction in the application of the ordinal numbers. By denying the claims of the olfactory lobes, and overlooking the fourth and sixth, the earlier anatomists made a smaller number; but the arrangement of Willis, which is more usually adopted in the present day, counts nine of these soft round cords, and reckons them from before backwards.

Yet even this apparently simple method of distinction comes far short of real accuracy. Thus, some of the so-called nerves offer the essential structure of nervous centres; and include, in addition to the ordinary nerve-fibres, those globular vesicles which modern physiology recognizes as the generators of the nervous force. In others of them, the limited resemblance implied by this numerical arrangement is modified by their arising as two or more roots, which subsequently, by their junction, form one nerve. While in the *seventh nerve*, which forms the subject of the present article, the close proximity of two such cords during a part of their course has led to their being united under one name; although in their distribution, properties, and functions, they present a marked contrast with each other.

The *facial* and *auditory* nerves proceed together from the medulla oblongata to the bottom of the meatus auditorius internus in the petrous portion of the temporal bone. Up to this point they are included in the term seventh nerve; but beyond this situation their courses widely diverge. In conformity with these differences, the following short account will describe them separately from each other. It will first mention such of their anatomical features as are manifest on simply laying bare their surface, and will afterwards refer to the appearances afforded by a more artificial dissection or separation of their fibres. Subsequently we shall briefly examine the bearing of these their structural peculiarities, and the effect of their morbid changes, with a view to attempting the deduction of their function.

The *auditory nerve* is of a considerably softer texture than the facial; a difference which is in great part attributable to the much more delicate neurilemma by which it is enveloped, but which is, no doubt, to some extent the result of a peculiarity of its constituent nerve-

* Vol. I. p. 286. † Meckel.
‡ Vol. I. p. 288.

fibres. From the fact of its lesser consistence, it is frequently termed the "*portio mollis*" of the seventh nerve.

Its apparent *origin* is close to that of the facial. At the upper part of the lateral surface of the medulla oblongata, a somewhat triangular depression exists, which is bounded in front by the olivary body, above by the lower border of the pons varolii, and behind by the restiform body. This shallow cavity has been termed by Vicq d' Azyr "the fossa of the olivary eminence," and in it appears the commencement of the auditory nerve.

On dissecting out this origin, however, it may be separated into two portions or roots. One of these immediately penetrates the restiform body at a right angle to its surface, and sinks into the central grey matter of the medulla oblongata: while the other, continuing backwards superficially to the restiform body, winds round it to reach the floor of the fourth ventricle, where this structure is deficient. By this latter root, the nerve seems to be directly continuous with the tranverse white fascicles of the calamus scriptorius; and near the middle line, it sinks into the posterior part of the same grey mass of the olivary columns, into which the other portion was followed.

But considerable variations appear to prevail in the degree of the visible continuity of this root with these transverse white striæ. Thus Meckel and Prochaska remarked that they are sometimes wanting; while Longet * confirms their statements, and adds, from the experience of himself, Serres, and others, cases which show that not only is their number variable within certain limits, but that, even where present, they may not unite with the root of the auditory nerve, but may curve upwards at their extremity, and pass up the posterior surface of the mesocephale. One or two examinations made by the author of this article seem to show that this is by no means unusual.

Other and more complicated origins have been ascribed by various anatomists to the auditory nerve. Thus, according to Foville †, a thin and white nervous lamina, which is continued from its roots and from those of the fifth nerve, is spread over, and as it were lines, the interior of the cortical grey matter of the cerebellum, in addition to covering the whole surface of the fourth ventricle and medullary velum. But in this and other descriptions of a like tendency, it seems difficult to distinguish how much of the connection observed was referrible to a mere physical contiguity of the soft nervous matter, apart from that unbroken continuity of nerve-tubules which we are probably justified in predicating of the cerebral nerves and their more immediate processes of origin.

From the place of its first appearance at the surface of the encephalon, the nerve passes, in a direction which is at once forwards, outwards, and upwards, to the inner surface of the petrous portion of the temporal bone, where it enters the internal auditory meatus. In this course, the flocculus, an isolated lobule of the cerebellum, is in close proximity with its outer side; while on its inner side, and in front of it, is the portio dura, which slightly grooves this surface of the somewhat flattened auditory nerve.

After entering the auditory canal, it continues along it to its termination; and, finally, at the bottom of the meatus, it divides into two branches. The anterior of these is distributed to the cochlea: and the posterior, which exhibits a small gangliform enlargement, supplies the vestibule, dividing into three branches; one for the posterior vertical canal, another for the sacculus, and a third for the utriculus, and remaining semicircular canals. These several divisions perforate the numerous foramina which are found at the bottom of the meatus to enter the internal ear; but as an account of their further arrangement with respect to the parts they supply would require a description of the auditory apparatus itself, the reader is referred to a previous article, "ORGAN OF HEARING," in which these details will be found included.

The *facial nerve*, the "portio dura" of the seventh pair, emerges from the same depression in the restiform body which was above described as giving rise to the auditory. It is of a much firmer and harder consistence than the latter, the tubules which compose it being connected by, and included in, a firm and strong neurilemma. Its real origin is generally referred to that central grey matter of the olivary columns to which so many of the encephalic nerves are traced. It is difficult to follow it any depth beyond these in a satisfactory manner; but Foville considers that it may be traced in the transverse direction around the olivary column and anterior pyramid, and hidden beneath the lower margin of the pons varolii, to an origin from the inner border of the pyramid. He corroborates this by a reference to its comparative anatomy; and states that the various stages of this course are successively laid bare by that diminished development of the lower arches of the pons which occurs in many of the mammalia. The description given by Morganti * somewhat differs from this, since he describes its roots as radiating by many filaments, ascending, descending, and transverse; and the latter joining more deeply the central grey substance of the medulla oblongata near the floor of the fourth ventricle.

The description of the facial nerve may be conveniently separated into three parts: each representing a distinct stage of its course, which is accurately defined by its anatomical relations to the skull. The *first* of these is *intra-cranial*, and extends from the surface of the encephalon to the termination of the internal auditory canal. The *second* is *osseous*, and reaches from the latter point to the stylo-mastoid foramen, which forms the exit

* Anatomie et Physiologie du Système Nerveux, tom. ii. p. 84.

† Traité Complet de l'Anatomie du Système Nerveux Cerebro-spinal. Première Partie.

* Annali Universali di Medicina. Giugno, 1845.

of the nerve from the aqueduct of Fallopius. The *third* is *extra-cranial*, and includes its distribution on the exterior of the skull beyond this aperture.

In the cranium, the course of the facial nerve is comparatively short. From the restiform body it passes forwards, lying immediately beneath and in contact with the pons varolii, and taking the same direction as the portio mollis, which is external and posterior to it. It next enters the meatus auditorius internus in company with this nerve; and finally leaves it by passing through the aperture at the upper part of the termination of this canal, and entering the aqueduct of Fallopius.

Portio intermedia.—With this part of the auditory and facial nerves a third portion is visibly associated; which is, in all probability, essentially distinct from both. Wrisberg first announced the existence of this nerve as a separate branch; and from its occupying a position between the "portio mollis" and "portio dura" of the seventh, he named it the "portio media" or "intermedia." It arises by two or three filaments from the restiform body, in the same locality as the neighbouring facial nerve, from which its deeper origin can scarcely be separated. Foville, however, describes its ultimate visible fibres as traceable to a situation which is intermediate between that of the facial on the one hand, and that of the auditory on the other. He thus considers these three nerves, the facial, intermediate, and auditory, as arising respectively from the anterior pyramid, the olivary column, and the restiform body; or to use his own language, from the anterior, the lateral, and the posterior tracts of the medulla oblongata. Morganti's view of its origin closely approximates to this; but he places it more in connection with the vestibular nerve, and hence more externally. But whatever may be the differences of opinion as to its exact mode of commencement, it is tolerably agreed that it is in very close proximity to the facial nerve, so much so as at first hardly to be separable from it; and that, at a further stage of its course, it is attached to the vestibular branch of the auditory nerve. Concerning its behaviour subsequently to this point, anatomists are less unanimous. Thus, some imagine that it continues engaged in the auditory nerve, and accompanies it into the internal ear. Others regard it as returning to the facial nerve, and passing with it into the aqueduct of Fallopius. It is, however, sufficiently evident, that the only correct foundation of any of these views must be anatomical; and since this method of investigation requires not only the artificial unravelling of the trunks, but also necessitates a frequent reference to portions and branches of the facial, as yet undescribed, its consideration is deferred until these shall have received some notice.

In the temporal bone.—The facial nerve, entering the aquæductus Fallopii from the internal auditory meatus, passes, for a very short distance, in a direction forwards, outwards, and slightly upwards, until it reaches the margin of the hiatus Fallopii on the upper surface of the petrous bone: it then suddenly bends backwards upon itself in the horizontal plane. Its next curve differs from the preceding both in character and direction, being much more gradually effected, and occupying a vertical plane. The termination of this bend reaches the perpendicular, and opens by the stylo-mastoid foramen on the under surface of the petrous bone, or between the styloid and mastoid processes. In the middle of this course the osseous tube of the aquæductus Fallopii projects into the cavity of the tympanum; and the nerve thus passes successively along its roof, above the fenestra ovalis, and then behind the pyramid on the inner side of the cavity; and, finally, down its posterior surface.

At the anterior of the acute angle formed by the first bend of the facial nerve in the aqueduct of Fallopius, it experiences a slight enlargement, which has been called, from its position and shape, the "intumescentia genuformis." A dense and strong neurilemma here ensheaths the nerve, being a prolongation of dura mater, which is sent inwards on a minute vessel from the middle meningeal artery to enter the canal at the hiatus Fallopii. The swelling itself is of a greyish-red colour, but it is somewhat obscured by this thick covering of fibrous tissue. Its nature will be spoken of hereafter.

Just at this point, *the superficial petrosal nerve* is connected with the facial. Tracing it forwards from the intumescence, it is seen to pass at once through the neighbouring hiatus Fallopii, and thus it immediately gains the interior of the skull. Within the cranium it passes forwards, downwards, and inwards, lying in a groove on the outer or anterior surface of the petrous bone, and situated beneath the Gasserian ganglion of the fifth nerve. According to some anatomists, it occasionally passes amongst or through the meshes of the gangliform structure. Still beneath and internal to the ganglion, it is next placed immediately external to the internal carotid artery, where this vessel, emerging from the canal of the same name in the temporal bone, springs vertically upwards to form the commencement of the posterior limb of the sigmoid turn on the side of the sphenoid. It thus enters the foramen lacerum basis cranii, perforating the cartilaginous substance which closes this bony orifice; and in this manner it gains the posterior extremity of the vidian canal, which opens into the anterior aspect of this irregular opening. Finally, it continues along this canal to its anterior termination; and is then prolonged horizontally forwards for a short distance to join Meckel's ganglion, which occupies this part of the spheno-palatine fossa.

Another nerve comes off from the same knee-shaped bend of the portio dura; and as it appears from the same horizontal slit, or hiatus Fallopii, whence the preceding emerged, and occupies a very similar position with respect to the temporal bone, it has also been named "superficial petrosal," but is distin-

guished, from its lesser size, as the "*small petrosal nerve*." From the hiatus it is continued forwards and slightly inwards for about half an inch, running along the same surface of the temporal bone, but placed a little external to the preceding nerve. Arriving at the greater wing of the sphenoid, it perforates the bone by an oblique and minute orifice, which is situated between the foramen rotundum and ovale: and appearing on the inferior surface of the base of the skull, it immediately unites with the otic ganglion which lies on the inner surface of the third division of the fifth. During the latter part of this course it is accompanied by a filament from Jacobson's nerve of the glosso-pharyngeal. This branch, however, leaves the tympanum by a special canal, and is next placed externally to the lesser petrosal nerve on the petrous bone; but, finally, it joins or runs with it to enter the same ganglion.

A *branch to the membrane which closes the fenestra ovalis* is sometimes described as coming from the facial, where it passes, in the aqueduct, above this orifice.

The minute *filament to the stapedius* muscle is the next branch of this nerve. It leaves the portio dura and aquæductus Fallopii at about the middle of their second or vertical curve, or nearly on a level with the base of the promontory; it next enters a small canal in this prominence, which conducts it to the proper osseous cavity for the muscle: it then breaks up and is lost in its substance.

The *chorda tympani*, the next connection of the portio dura, is a much larger nerve than any of the preceding branches; it leaves the trunk of the facial at a distance of about the third of an inch from the stylo-mastoid foramen. Tracing the portio dura in the upward direction, it is first seen to experience a slight thickening, and gradually, by the increasing laxity of the connecting areolar tissue, a tolerably large branch seems to extricate itself from the trunk at a very acute angle. Diverging still more, it now altogether quits the aquæductus Fallopii, and enters a short canal which is appropriated to it, and which is placed anteriorly and externally to the former cavity, occupying the base of the promontory. While yet at a considerable distance from the apex of this eminence, the nerve emerges from its canal by an orifice very near the osseous ring to which the tympanic membrane is fixed. It now crosses the tympanum from its anterior to its posterior part, and lying close to its outer wall, but covered by a reflection of its mucous membrane, and ascending as it goes, it passes between and at right angles to the long process of the incus and the handle of the malleus, to reach the processus gracilis of the latter bone; along this process it continues during the remainder of its course in the tympanum. It next leaves the anterior wall of this cavity, and occupies a minute canal in the petrous portion of the temporal bone; but it is still in close proximity to this process of the malleus, being only separated by a small interval of bone from the Glasserian fissure which contains it. It is next seen external to the cranium, after coming through the aperture of this canal anteriorly and internally to the fissure. In the remainder of its course it lies deeply in the pterygoid fossa beneath the ramus of the inferior maxilla, and is directed for about an inch downwards, forwards, and inwards, beneath the spinous process of the sphenoid, and the internal lateral ligament of the lower jaw attached to it, to join, at an acute angle, the outer side of the gustatory branch from the third division of the fifth.

Very near the termination of the aqueduct of Fallopius, a minute *twig connects the facial and vagus* nerves. Following it from this cavity, it is seen to enter a small pore on its anterior surface, which conducts it by a short canal to the under surface of the petrous bone, where it emerges a very short distance in front of the stylo-mastoid foramen, and between it and the jugular fossa. The nervous filament now turns inwards and forwards in front of the jugular vein, and terminates by connecting itself with the pneumogastric, just below its ganglion in the dura mater of the foramen lacerum posticus.

Besides these branches of the facial within the aqueduct, it appears pretty constantly to give off, while yet contained in this canal, a filament which passes inwards behind the jugular vein, and joins with the *glosso-pharyngeal* just below the ganglion of Andersch. Longet states that this branch, after its junction with the glosso-pharyngeal, may generally be traced to the digastric or stylo-hyoid muscle, in which it often unites for the first time with this nerve by a kind of plexiform arrangement.

External to the cranium. — On leaving the Fallopian canal, the facial nerve immediately enters that portion of the parotid gland which dips downwards behind the styloid process to reach the structures lying deeply at the base of the skull. The nerve next continues through the substance of the gland, being directed forwards and inwards to about its middle, where it divides into its temporo-facial and cervico-facial portions, the ramifications of which cover the whole side of the face, with part of the neck below and the head above. In its short course previously to this bifurcation, it gives off three branches, the posterior auricular, the digastric, and the stylo-hyoid nerves.

The *posterior auricular*, the first branch of the facial without the skull, passes upwards from the trunk of the nerve, and turns round the front of the mastoid process, lying at first rather deeply in a depression between the auricle of the ear and this prominence, and being enveloped in a dense cellular tissue. Having gained the side of the head, it divides into two branches; one of these continues backwards in the horizontal direction, above the insertion of the sterno-mastoid, and crossed by the lesser occipital nerve of the cervical plexus, to reach the posterior belly of the occipito-frontalis muscle, which it supplies: in this course it is covered by a dense fascia, and is

in close proximity to the artery which bears the same name. The remaining branch of the nerve takes a vertical direction, ascending perpendicularly behind the ear through the fleshy bundles of the retrahens aurem. To this muscle it is chiefly distributed; but a few of its filaments continue to the posterior surface of the auricle, probably to supply its transverse muscular fibres. The trunk of the posterior auricular nerve, or some one of these its branches, is usually found to be joined by filaments of the great auricular nerve from the cervical plexus, and more rarely by some twigs from the lesser occipital branch of the same plexus. Arnold also describes a filament of the auricular of the pneumogastric uniting with it.

The two following branches not unfrequently arise by a common trunk. The *digastric*, the larger of the two, leaves the facial nerve to penetrate the posterior belly of the digastric muscle, and supply it with many filaments. One of its branches, of more considerable magnitude, perforates its substance, and passing directly inwards, joins the glosso-pharyngeal immediately on its emergence from the skull. Other filaments of smaller size are said to join the superior laryngeal of the pneumogastric.

The *stylo-hyoid* branch, leaving the trunk of the portio dura near the preceding, passes downwards, forwards, and inwards; crossing the styloid process obliquely, then running along the upper border of the muscle, and finally penetrating its fibres to be distributed to its interior. It is believed to unite, by numerous minute twigs, with the sympathetic around the neighbouring carotid vessels.

At the place of its division, the nerve occupies a position in the parotid gland which is superficial to the many other vessels and nerves found here; and especially, at right angles to the external jugular vein and carotid artery.

The *temporo-facial division* or branch is larger than the cervico-facial; it passes forwards and upwards over the condyle of the lower jaw, and joins, towards the zygoma, with one or two large branches of the auriculo-temporal nerve. This comes from the third division of the fifth in the pterygoid fossa; and the place of its union with the portio dura is in close proximity to the external carotid artery. The intimacy of the junction which connects the two nerves has probably led some anatomists to describe this temporo-facial branch as giving many filaments to the front of the ear. These, however, with many others which ramify in the gland itself, belong to the associated branch of the fifth, and not to the portio dura.

Beyond this its junction with the fifth, it is no longer possible to trace any special nerve, or to indicate its subdivisions by names, since, on the masseter, a succession of diverging branches are given off from it, each of which, by uniting with its neighbours above and below, and giving off fresh ramifications from the branches of union, forms part of a complicated network, in which the original constituent branches, and the respective shares which they take in the new loops, can scarcely be recognized. Cruveilhier and Bonamy have traced this looped arrangement still more minutely, having followed it into the smallest branches of the nerve, and especially into those which supply the orbicularis; and it has been likened by them to the mode in which the mesenteric arteries break up to reach the intestine.

Notwithstanding this free communication, however, the different portions of this reticulated arrangement may be conveniently regarded in succession, in order the better to appreciate their distribution.

Superiorly are the *temporal* branches; these emerge from beneath the upper border of the parotid, and cross the zygoma to be distributed to the superficial muscles of the auricle, the attollens and attrahens aurem, and to the anterior belly of the occipito-frontalis beyond these. The orbital branch of the second division of the fifth joins, by its long ascending filaments, with these branches of the facial; so also a perforating filament from the deep temporal of the third division, with others from the auriculo-temporal of the same portion of the fifth, are usually traceable to an union with this nerve.

Anteriorly to these are the numerous *orbicular* or *supra-orbital branches*. They pass obliquely forwards and upwards over the malar bone, to supply the orbicularis palpebrarum, and corrugator supercilii muscles. Their connection with the fifth occurs chiefly by the supra-orbital and lachrymal of the ophthalmic division; but others join the malar branch of the second division, where it emerges from its foramen in the malar bone near the outer angle of the orbit.

The *infra-orbital* filaments pass almost horizontally forwards from the temporo-facial division towards the side of the nose. In this course, accompanied by the parotid duct, they cross over the masseter muscle; and more anteriorly, they pass beneath the different muscles which descend to the angle of the mouth and upper lip, and are distributed to them by numerous filaments which enter their deep surface. In this manner the greater and lesser zygomatic, with the proper and common elevator of the lip, and the elevator of the angle of the mouth, receive their nervous supply; and the pyramidalis and transversalis nasi also obtain filaments from this part of the facial. Many of these, in passing forwards, unite at right angles with the radiating bundles of filaments into which the infra-orbital nerve divides after leaving the foramen of the same name. Besides this union with the second division of the fifth, it unites with the ophthalmic by a small twig of its nasal branch, which appears between the lateral cartilage and the nasal bone, and generally by an infra-trochlear filament of the same portion in the angle of the eye.

The *buccal* branches, with the same direction as the preceding, occupy a position at a somewhat lower level on the face, in the neigh-

bourhood of the transversalis faciei artery. They mostly terminate in the upper half of the orbicularis oris, and in the buccinator, on which muscle they join with the buccal branch of the inferior maxillary division of the fifth. This latter nerve is distributed to the mucous membrane and integuments, and probably has no share in the supply of the muscle. The lower of these buccal branches join another portion of the network, which results from the ramification and union of the next division of the facial.

The *cervico-facial division*, of smaller size than the temporo-facial, passes downwards and forwards from the seat of bifurcation of the portio dura, and emerges from the parotid gland near the angle of the lower jaw. Here it divides and subdivides in the same manner as the preceding portion. It is divided into a facial and cervical, or a supra and infra-maxillary part.

Its *supra-maxillary* part is constituted by one or two large branches, which, breaking up as they pass forwards to the interval between the jaw and mouth, enter beneath the platysma and triangularis menti; and besides supplying these and the other muscles of this region, they join with a branch of the inferior dental which comes through the mental foramen.

The *infra-maxillary*, or cervical portion of the facial nerve, consists of two or three branches, which, directed still more obliquely downwards, soon divide into very numerous filaments. These pass beneath the platysma to gain the upper and anterior part of the neck, where they form looped ramifications, the most inferior of which are traceable in a vertical direction to a short distance below the hyoid bone. They are chiefly distributed to the platysma, and above they join with the neighbouring supra-maxillary branches just mentioned. They unite beneath the platysma with one, or more usually with two, branches from the superficial cervical nerve of the cervical plexus, which turns round the posterior border of the sterno-mastoid muscle to supply the integuments of the same part of the neck.

Little can be said with respect to the exact nature of these very numerous junctions of the facial nerve, either with the terminal branches of the various divisions of the fifth, or with the cutaneous nerves of the cervical plexus. They offer a very obvious anatomical resemblance to that intermingling of different nerves which constitutes a plexus; but without here specifying other distinctions, it may suffice to point out that, in many instances, the branches of the facial seem visibly continued in their previous direction beyond their connections with the fifth. In the absence of more minute investigations, this apparent independence can only be received as indicating a partial involvement of the two nerves, or an incomplete mixture of their fibres, in which one gives to the other, or each gives to each, a small number of its filaments, but retains the large majority.

We next proceed to consider those minuter features in the anatomy of the seventh nerve, which require a more artificial dissection or examination for their verification.

The origin of the portio intermedia, rather more externally than the facial, has been already spoken of, and the nerve was then traced to an union, more or less complete, with the neighbouring vestibular portion of the auditory nerve. Beyond this point the views adopted respecting it, from being somewhat conflicting, become absolutely discordant.

The very different nature of the numerous opinions upheld by various anatomists precludes the possibility of enumerating them here at full length. Some of these, however, have been already very briefly noticed; and perhaps, on the whole, the most prevalent was that which supposed the portio intermedia to give a branch which united with the vestibular nerve, while the remaining portion passed itself into the facial.

More recently, the anatomy of the distribution and connections of this nerve seems to have been fully made out by Morganti in an elaborate monograph on the Geniculate ganglion *; which is, I believe, chiefly known in this country through the medium of an excellent analysis contained in one of Mr. Paget's Reports.† By careful dissection of the nerves, which he had previously hardened in nitric acid, Morganti succeeded in unravelling their filaments; and thus in separating the portio intermedia from the facial and vestibular nerves to a much greater extent than had hitherto been accomplished. The general result of this process was, that many of the so-called anastomoses were shown to be mere relations of propinquity, due to an intricate entanglement, but not implying any real junction or interchange of fibres.

In the human subject.—The portio intermedia (*fig.* 405, *b*), shortly after its origin, and

Fig. 405.

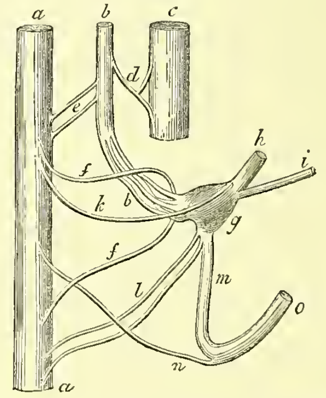


Diagram of the Portio intermedia and its branches. (After Morganti.)

* Op. cit.

† Report on the Progress of Human Anatomy and Physiology in the year 1844-5. British and Foreign Medical Review.

while lying closely by the side of the vestibular branch of the auditory nerve (*c*), gives off a filament (*d*), which passes towards it. Before joining with it, however, a similarly small branch which comes off from the latter nerve, unites with that previously given from the portio intermedia, and the common trunk thus formed passes into and is lost in the vestibular nerve.

The intermediate nerve next emits two small filaments (*e*), which join the portio dura, and cannot be satisfactorily traced through its trunk.

The description is now complicated by the introduction of a large branch of the facial (*f*) which emerges from it to take a spiral course around the portio intermedia; and which, after running with it for some distance, returns to the facial at a lower point than that from which it set out.

Setting aside this fictitious junction, the whole of the portio intermedia, after the giving off of the facial and auditory branches, was traced into the genuform intumescence: this, it will be recollected, is seated on the first bend of the facial in the Fallopian canal, and close to the hiatus of the same name.

The nature of this intumescence is the next question to which the description directs itself, and is perhaps even more important than the preceding dissections. The appearances of this swelling, and its reddish-grey colour, had long given rise to conjectures of its ganglionic nature. Many anatomists, indeed, have affirmed its identity with the true ganglions. By others, however, it has been somewhat obscurely described as intermediate in structure between a ganglion and a gangliform enlargement: a description which can only be understood as indicating their doubt of its ganglionic character, since the supposition of such a gradation of texture is perfectly gratuitous. And others have altogether denied its ganglionic characters; attributing its colour to the minute vessels which pass through the hiatus Fallopii to the facial nerve and internal ear, and explaining the appearance of enlargement or intumescence by the divergence of the fibres of the superficial petrosal nerve where it joins the facial.

With the question of the ganglionic structure of this body has necessarily been mixed up that of the course taken by the nerves which arise from it, and their relation to the facial. Indeed, the negative side of the argument — the denial of the ganglion — perhaps requires its advocates to explain the real nature of the swelling, and to show the arrangement of its supposed constituent nerve-fibres. But in the present day at least, the affirmative of the question may be justifiably reduced to the detection, in the so-called ganglion, of the globular vesicles which are essential to the structure of a nervous centre.

It is singular that for a considerable time this simple method of settling the disputed nature of the intumescence should either have escaped notice or failed to afford any satisfactory results: the latter seems to have been sometimes the case; but more frequently, perhaps, this method of proof or disproof was overlooked. The discovery of the ganglion corpuscles, and thus the establishment of its ganglionic nature, belongs to Morganti. He describes it as consisting of meshes or reticulations of nerves, the intervals of which are filled by a yellowish ash-coloured substance. In the latter, he states himself to have verified the existence of these bodies.

The essential part of this description I am able to confirm. It appears difficult to obtain specimens from the human subject in a state sufficiently fresh to observe these delicate and easily decomposed corpuscles. In the lower animals, however, this difficulty is no longer met with; and many of them present the additional advantage of a much less dense neurilemma than that which is present in the human structure. After removing the brain of the sheep, the ganglion may thus be easily exposed and removed, preferably with the nerves still attached to it. Cutting off the attached extremities of these, and very gently and imperfectly tearing up the ganglion which remains, completes the preparation of the specimen. Under these circumstances, the corpuscles of the grey matter are readily visible. They are of an oval or roundish shape, and of a very large size, which amounts in the average to about the 1-200th of an inch. In the uninjured parts of the specimen, they appear to be disposed with considerable regularity, each being in contact with several others by a part of its surface. On a rough calculation, the ganglion contains about three or four hundred of these corpuscles. The contents of the corpuscles are of the ordinary kind. A nucleus occupies some portion of their inner surface, and a large quantity of the usual granular substance fills up the remainder of their interior. Most of them also contain a quantity of pigment towards one extremity of their ovoid cell-cavity. This is disposed as a dark brown mass of an oval form, and some of these masses, when seen isolated by the accidental rupture of their containing vesicles, have exhibited a defined and sharp outline, which induces me to suspect their inclusion in a cell membrane, separating them from the rest of the contents of the vesicle. Rarely there are appearances of short processes from these vesicles. Nerve tubules in rather sparing quantity are found in contact with these large cells, mostly occupying their interstices, or coiled around their circumference; and the periphery of the ganglion itself is surrounded by a kind of layer of them: these appearances, however, seem distinctly traceable to the mechanical violence employed in the examination, which forces the tubes into the situations of least pressure; and one cannot, therefore, regard them as affording the least insight into the mode in which the nerves are arranged with respect to the vesicles.

From this ganglion emerge, or rather to it are attached, the following branches: — 1. and 2. The superficial petrosal nerves, the greater of which (*fig.* 405, *h*) passes to the

spheno-palatine, and the lesser (*i*) to the otic ganglion: the first of these Morganti has depicted receiving a filament (*k*), which comes from the facial, and in its course to the petrosal nerve passes over the ganglion without joining it. The second or lesser of the two appears to be derived solely from the ganglion. 3. A large branch (*m*) which forms the great bulk of the chorda tympani; but, in order to this, is also joined by one or two filaments (*n*) from the facial nerve, which accompanies it in the Fallopian canal. 4. Branches (*l*) which passing downwards are lost in the trunk of the portio dura.

The annexed diagram, (*fig.* 405.) with the letters attached to it, will assist the reader in following this otherwise intricate description. It is taken from a drawing by Morganti in the essay referred to; but it has been reduced in size and simplified, so as better to allow of its introduction here.

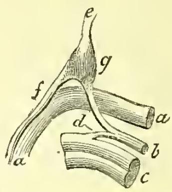
The same author has examined into the comparative anatomy of the ganglion and the nerves connected with it in many of the other mammalia, as the dog, calf, lamb, mule, and dormouse.

The general results of these examinations abundantly verify his description of the arrangement in the human subject. Indeed, these animals offer by far the most favourable subjects for exemplifying the truth of the preceding description, being, as Morganti remarks, natural preparations of these parts. Not only is the dense and intimately adherent sheath of fibrous tissue, which is present in man, much looser in the ganglion and nerves of these animals, but the position of this body with respect to the nerve is considerably altered. The much less marked anterior bend of their portio dura occurs at some little distance from the hiatus Fallopii; and the ganglion, which is in immediate proximity to this aperture, is thus no longer *geniculate* in its position, being removed from the *knee* of the facial. Hence it is, as it were, out of the way of the facial branches, and ceases to be entangled amongst them, as in the human subject.

The author of this article can bear testimony to the accuracy of these statements; indeed, any one may easily verify them for himself, in most of these animals, with scarcely more trouble than removing the brain and osseous roof of the Fallopian canal, and then stripping off the comparatively lax neurilemma from the subjacent ganglion and nerves. The accompanying sketch (*fig.* 406.) was taken from the left side of a sheep's head. With as little artificial separation as possible, it represents the arrangement of the ganglion and nerves *in situ*, especially the manner in which the trunk of the portio intermedia crosses the facial nerve without joining it, and the apposition or proximity, without mingling, of the ganglion and the latter nerve.

The varieties of arrangement which obtain in the different animals whose nerves Morganti examined, are chiefly, as might be expected, differences in the degree of interlacement of the adjacent nerves. In particular, that of the portio intermedia with the

Fig. 406.



Auditory, Facial, and Intermediate Nerves of a Sheep as seen in situ. Magnified about $2\frac{1}{2}$ diameters.

a, portio dura; *b*, portio intermedia; *c*, portio mollis; *e*, origin of the superficial petrosal nerves; *f*, chorda tympani; *g*, geniculate ganglion.

vestibular nerve is sometimes so complete and intricate, as to render it in such instances difficult to ascertain from their examination only, whether the former of these nerves gives branches to the latter, or, *vice versâ*, this to that. In the mule, he exhibits a filament from the facial to the ganglion; but thinks this a possible restitution of one or both of the two previously given to it by the portio intermedia.

The general anatomical conclusion to be drawn from these details is, that the facial nerve—as implying in this term both the portio dura and the portio intermedia—arises by two roots. Upon the smaller of these a ganglion is formed, while the latter is entirely devoid of such a structure. The branches of the facial nerve in the Fallopian canal are mixed nerves, being formed partly by filaments from the ganglion; partly also by filaments from the aganglionic root; the latter being in considerably lesser numbers. And the trunk of the facial itself, beyond the ganglion, is also a mixed nerve, since, although by far the greater part of its bulk consists of fibres from the greater root, yet it also contains one or two filaments which come from the ganglion. The analogy of this arrangement to that of the spinal nerves is sufficiently obvious, and will be hereafter again referred to.

It deserves to be mentioned in this place, that many other accounts of the arrangement of these nerves might easily have been added from various authors, but that all of them are more or less at variance, both with the above description by Morganti, and with each other. It has seemed fit, however, to assign these a very subordinate position in the present short article, since the verification of a ganglion belonging exclusively to the portio intermedia includes not only the denial, but I think we may add the disproof, of many of these descriptions. So far as our knowledge of the structure of ganglia at present extends, and whether the late brilliant researches of Rudolph Wagner* apply universally or not, we are at least justified in viewing with great

* Handwörterbuch der Physiologie. Siebenzehnte Lieferung. Artikel "Sympathischer Nerv Ganglienstruktur und Nervenendigung."

incredulity any account of the unaltered passage of a nerve through a ganglion, as viewed by the unassisted eye; and, in the particular instance before us, the microscope disproves this supposition. So, also, concerning the various theories of the derivation of the superficial petrosal nerves which have been set forth as based on dissections. Let it be granted that there are two ganglia, — the sphenopalatine and the geniculate, — which are united by an intervening nervous cord: in such a case, I cannot see how any merely anatomical skill would enable one to predicate a definite direction as taken by the connecting nerve. Indeed, any statement of this kind really amounts to asserting a special direction or quality of the nervous force, and to the affirmation or denial of such a view, the scalpel affords no assistance.

The unravelling of the nerves themselves, even as performed in the above dissections, requires, perhaps, to be received with considerable caution; and that natural separation or simplification which is afforded by their comparative anatomy must be regarded as vastly increasing the value of the results obtained. The chorda tympani affords a good instance of the conflicting results of these dissections, when unaided by this latter method of inquiry. Some have considered, with H. Cloquet and Longet, that, after remaining a short time in contact with the gustatory or lingual branch of the fifth, the whole of this nerve passes away from it, to form one of the roots of the submaxillary ganglion. Others have described it as only giving a filament to this ganglion, and uniting itself by the remainder of its bulk with the branch of the fifth; while others have failed to detect any direct transition of the chorda tympani into the ganglion, but, on the contrary, have found the two nerves inseparably mixed up below the situation of their visible junction. And more recently it has been traced by Guarini* to the lingualis muscle. On general grounds, the first of these notions is liable to much objection, since it seems singular that a nerve so far removed from the facial as the chorda tympani is at the base of the skull, should be involved in such an accidental proximity as this would make it, or should run so closely to the gustatory without any interchange of fibres. Again, the total passage of the nerve to the ganglion appears very improbable, when the relative size of the entering and emerging branches is considered, — that is, on comparing the bulk of the chorda tympani with that of the two or three filaments which join the ganglion, it may be seen that the former is larger than all of them together. This is especially the case in some of the lower animals, as the dog; in whom the submaxillary ganglion and its roots from the cerebral nerves are so greatly reduced in size as to be scarcely visible to the naked eye, while the chorda tympani continues a comparatively large branch. But these general objections will not apply to the supposition of a partial connection of the chorda tympani with the submaxillary ganglion, and the question must accordingly still remain in doubt.

* Annali di Medicina. Maggio, 1842.

Physiology of the seventh nerve. — The functions sustained by the *auditory nerve* are recognised with sufficient certainty. The anatomy of its distribution, its variations in the different classes of the animal kingdom, and the results of experiment or disease affecting its structure, all unite to indicate it as the nerve which, specially adapted at its periphery in the organ of hearing to receive impressions from the vibrations of the external air, conveys them to the brain, and by exciting corresponding impressions there, gives rise to the production of a sensation which we term a sound. For the further details of its function, reference is made to the article HEARING.

The facial nerve. — It has been seen from the preceding description, that the facial nerve is distributed almost exclusively to muscular structures; and, although these are very numerous, yet they all admit of being reduced to one class, viz. the muscles of the face. A further subdivision would next separate them into several groups, which serve to enlarge or diminish the size of the various apertures by which impressions are admitted to the organs of the special senses, as the eye, ear, nose, and tongue. But these orifices are also the pathways of food and air, so that the muscles which regulate their size have thus far an influence on the functions of respiration and digestion. In man, they fulfil the further purpose of organs of expression; their various and complicated adjustments conveying, for the most part, a tolerable index of the passions or emotions of the presiding mind.

This prominently muscular distribution of the facial would lead us to expect *à priori* that the nerve was chiefly motor in its function; and, if we turn from its anatomy in the human subject to its varieties of arrangement and appearance in the animal kingdom, this view will be abundantly confirmed. Not only is its peripheric distribution almost exclusively muscular, and in connection with the same facial set of muscles, but it also experiences a development which is co-equal with that of these organs, increasing with their augmented development, or disappearing with their suppression. Thus, in Fishes, the facial scarcely exists as a separate nerve. In Reptiles and Birds, its small size corresponds with the bony and immobile state of the face. In the Mammalia, it becomes much more considerable, and both the nerve and muscles experience various degrees of augmentation. Thus, in the monkeys it attains a large size, in accordance with the number and magnitude of the facial muscles generally; and the trunk of the elephant, and the muscular apparatus connected with the blowholes of Cetaceans, are supplied by large branches from this nerve, which here experiences a partial development, to meet the special exi-

gencies of the case. In man, the nerve attains the maximum of general development.

Experiment also confirms the testimony afforded by the human and comparative anatomy of the facial nerve: indeed, the results afforded by this method of enquiry first led Sir Charles Bell* to tho discovery of its function. On cutting across the trunk of the nerve, he found that the whole side of the face on which it was divided had completely lost the power of movement, while its sensibility remained unimpaired. His experiments have since been frequently repeated, and invariably with the same results.

The over-excitement of the nerve affords evidence of its motor function, equally with the destruction of its continuity. Thus, galvanism of the distal extremity of the cut nerve at once sets up convulsive movements in the muscles to which it is distributed.

The paralysis produced by section includes all those muscles which the facial has been previously described to supply; but the muscles of the jaw, which are furnished with nerves from the inferior maxillary division of the fifth, are still free to execute their contractions, and hence the movements of the jaw continue. But although these are still carried on, yet the act of mastication as a whole is rendered very imperfect; since this not only requires the apposition and trituration of the teeth upon each other, but also demands aecessory though subordinate movements of the neighbouring lips and cheek, and the section of the facial nerve distributed to these parts render these adjuvant movements impossible. In such cases an imperfect mastication may indeed be seen to take place; but the cheek and lips, having lost their contractility, instead of pressing in the food towards the teeth, and submitting it again and again to their action, allow it constantly and gradually to accumulate in this flaccid and yielding pouch; or permit it to fall out of the anterior opening in the mouth. In this instance, experiment throws a reflected light upon descriptive anatomy. The buccinator muscle, which forms the greater part of the fleshy parietes of the cheek, was previously mentioned as receiving branches from both the facial and inferior maxillary nerves; and were we to confide altogether in the appearances seen in dissecting these nerves in the human subject †, we might perhaps justifiably regard them as sharing between them the supplying of the muscle. But the paralysis of the buccinator, which is always present in those instances where the facial nerve has suffered division, points distinctly enough to the latter as at least taking the more considerable and important part of the two; while the failure of the galvanic stimulus to affect the muscle through the buccal nerve, indicates that the filaments of the facial are in all probability the only motor nerves which are distributed to it.

Many of those eases of paralysed facial nerve, which occur in the human subject as the effect of disease involving their structure, approximate closely to the results obtained by an artificial division of the nerve in animals; but in consequence of the much more expressive character of the human countenance in the normal state, the deviations produced are even of a more striking appearance. One half of the face forms a perfect blank, its muscles hanging passively from the subjacent structures; while the movements of the opposite side are distorted by the absence of their proper antagonist motions, and are exaggerated in appearance by the contrast.

In the experiments above mentioned, Sir Charles Bell found that immediately on dividing the nerve the muscular aperture of the nostril, which had previously been subject to an alternate dilatation and contraction during the periods of inspiration and expiration respectively, suddenly lost this movement. He has termed the portio dura *the respiratory nerve* of the face; since it presides over these and other motions of the facial muscles, which are developed independently of the will, and in answer to the necessities of respiration.

The section of the facial nerve indirectly affects the sense of *smell*. This fact was also first pointed out by Sir Charles Bell, and has since been confirmed by many other observers. Under these circumstances, the power of discerning strong odors, as tobacco and ammonia, appears to be much diminished on the affected side, although scarcely absolutely lost. This loss of smell has been ascribed to the absence of two causes greatly conducive to the exercise of this faculty in health. The muscular contraction of the nostril which accompanied the effort of snuffing effects a considerable narrowing of the aperture; and in the deep inspiration which accompanies the act, the rapidity of the entering current of air is thus greatly augmented, and in this greater velocity is implied an increased contact of the odorous vapour with the sensitive surface. Besides this, the direction of the current of air seems to be somewhat altered; the muscles, tending much more to constrict the posterior than the anterior parts of the orifice, appear to direct the current more upwards or anteriorly than in the ordinary inspiration. The mechanical nature of the action has been illustrated by Diday *, who has shown that dilatation of the nostrils by a glass tube, through which the air may be respired, equally prevents the perfect exercise of the olfactory sense; and Longet confirms his experiments.

The effect of division of the portio dura on

* Exposition of the Natural System of the Nerves of the Human Body. London, 1824.

† The lesser development of the facial muscles of the lower animals allows the distribution of the small buccal nerve to be more easily traced. Thus, in the dog, the two small filaments which form it pass, as is evident on dissection, almost exclusively to the mucous membrane and buccal glands.

* Gazette Médicale, 1838. Mémoire sur les appareils musculaires annexés aux organes des sens.

the *eye* is still more important. There is complete inability to close the eyelids of the affected side. This permanently open state is due to the action of the levator palpebræ, unopposed by the paralysed orbicularis palpebrarum; and the eye itself, no longer preserved from the contact of foreign bodies, or swept over by the conjunctiva which lines the eyelids, is often irritated into inflammation. The hazy vision which accompanies this condition is partly attributable to this cause; but more frequently depends on the imperfect removal of the lachrymal secretion, which becomes irregularly diffused in a more or less solid or dried state over the globe. The general relaxation of the orbicularis perhaps aids this, and it has also the effect of altering the position of the puncta lachrymalia, and thus preventing the natural exit of the secretion, which is sometimes poured down the face. But these effects are on the whole rarely so complete as is above stated; the aperture between the eyelids is usually small, and movements of the globe of the eye are to some extent substituted for those of the lids; so that the general results offer the most marked contrast to the rapid disorganization which follows the section of the fifth nerve which forms the sensitive supply of these parts.

Besides the influence of the facial nerve on mastication, as shown by the result of its paralysis or artificial division; the sense of *taste* appears to be considerably impaired on the corresponding side. This fact has been well illustrated by M. Claude Bernard *, who has collected nine or ten cases of this kind. The manner in which the sense is affected seems to vary. Thus, he describes it as an impairment, in which the most sapid substances failed to excite their ordinary impressions, and are only perceived after a considerable interval of time. Professor Roux has left a recital of his sensations during a rheumatic facial hemiplegia; and in his description, which Longet quotes †, he mentions that everything on the affected side tasted strongly metallic; whence it would appear that this *diminution* of taste is sometimes substituted by a *perversion* or depravation of the function.

And M. Bernard has conclusively shown that the *chorda tympani* is the immediate instrument of the change. He has adduced instances of paralysis from experiments, in which the facial nerve being divided above the point where this nerve diverges, the taste was constantly impaired; while in the facial paralysis due to disease of the nerve below its origin, the sense was unaffected.

In connexion with these facts may be mentioned the motor function of the chorda tympani. It has been previously stated that, among other courses ascribed to this nerve after its union with the gustatory, Guarini has succeeded in tracing its filaments to the lingualis muscle. But in addition to this, he has adduced experimental evidence of a much more conclusive character. He found that galvanising the fifth, ninth, and facial nerves affected the muscles of the tongue in a very different manner. When the sensitive nerve was stimulated, the tongue remained without movement; but in the case of the ninth and facial, an upward and downward movement was perceptible. When the hypoglossal was galvanised, a backward and forward motion was added to this common movement; while on stimulating the facial nerve, the middle tract of the tongue, which had remained tranquil in the previous experiments, was agitated in a vermiform manner. This latter movement was instantly annihilated by section of the chorda tympani. The region which it occupied was that of the lingualis muscle, and to it he traced some branches of the nerve: while the upward and downward movement belonged to the stylo-glossus. The cause of the affection of the taste is very imperfectly understood; since, in the case of the tongue, it seems difficult to connect such an impairment of the special sense with any mere loss of motion. Bernard has, however, offered such an explanation; in which, as a preliminary, he supposes a vermiform movement like that observed to be necessary to taste, and that it acts by increasing the contact of the papillæ of the tongue with the sapid particles. And although this is sufficiently unlikely, yet it is advisable to recollect that, unless guided by experience, we might have asserted the same improbability in the instance of smell; while this sense has been seen to experience an equal impairment, and in a method very similar to this which Bernard has supposed: — viz. by a diminution of effective contact between the object of the special sense and the distribution of its nerve, which contact is itself in part the result of the contractions of certain muscles, supplied by branches of the facial.

The mixed nature of the chorda tympani, as laid down by Morganti, may perhaps explain these effects in a different manner; by suggesting that the paralysis of this nerve involves the loss of some of the sentient as well as motor filaments distributed to the tongue. And the varieties in the nature of the affection which were indicated above, perhaps render this explanation a more probable one.

A connection has also been traced between the paralysis of the portio dura and an abnormal state of *the soft palate*: — the curtain of the palate itself being somewhat relaxed, while the uvula is drawn towards the unaffected side. In a great number of facial palsies, however, this deviation is absent. But although materials on this point are yet somewhat few, it may be safely stated that its presence or absence varies according to the seat of the disease causing the paralysis: if above the geniculate ganglion, the deviation appears pretty constantly present; if below, it is absent. The light which ex-

* Archives Générales de la Médicine, 1843, 1844.
† Op. cit. tom. ii. p. 465.

periment affords is somewhat uncertain and conflicting. Mechanical irritation of the root of the facial nerve in various animals has failed to excite contractions of the muscles of the palate, both with Valentin* and Hein.† The stimulus of galvanism has also acted irregularly and variably, being sometimes followed by contractions, sometimes not. It is, on the whole, difficult to avoid coming to the conclusion that the facial nerve is intimately associated with the movements of the palate by its greater petrosal branch: but the actual transmission of its uninterrupted filaments through the spheno-palatine ganglion is, on anatomical grounds, exceedingly doubtful. And the experiments above mentioned, together with others in which Hein found that its division did not affect pre-existing movements from other nervous sources, render the term "motor nerve" clearly an inapplicable name.

Concerning the influence of the facial nerve on *hearing*, little is known at present. Longet, in quoting the above case of M. Roux, in which comparatively faint sounds were painfully distinct, has given a very probable and ingenious explanation of the fact, by pointing the derivation of the nerve to the tensor tympani from the otic ganglion, which is itself associated with the geniculate ganglion and facial nerve. Regarding this muscle as the regulator of the acoustic drum, and the tension of this as the means of moderating excessive stimulus, just as the iris does in the eye, he shows the probability that the paralysis of the tensor in this manner deprives the ear of an important protection, and increases the loudness of the sound received.

It has thus been deduced that the facial is chiefly a nerve of *motion*; or, in other words, that by its central and peripheral organization it is adapted to determine the contraction of the facial muscles. It has next to be considered whether it is exclusively motor, or whether, on the contrary, it contains a certain proportion of nervous filaments, the office of which is the production of *sensations*.

The highly sensitive integument which forms the surface of the face, evidently receives its nervous supply solely from the different divisions of the fifth; and the anatomy of the distribution of these branches is confirmed by comparing the results which are obtained by artificial section of the facial and fifth nerves. In the case of the divided portio dura, it was previously mentioned, that while motion is lost, sensibility is unaffected; while in the common instance of the divided fifth, mobility remains, but the sensibility of this surface completely vanishes, and no expression of pain can be obtained even by cauterising large portions of the integuments.

The facial is thus excluded from all share in the tactile sensibility of this surface; yet it by no means follows that the nerve itself is wholly insensible. On the contrary, the experiments of most physiologists from the time of Bell agree in verifying the fact of its sensibility; as shown by the expressions of pain which are called forth on mechanically irritating the nerve in the living animal. Thus, pinching the trunk of the facial, or any of its larger branches, or the act of section itself, have been constantly found to be accompanied by the most unequivocal indications of suffering.

From the evidence above stated, it is manifest that the sensory filaments which we must suppose the trunk of the facial to contain, are not distributed to the cutaneous surface of the face. But although the skin is the chief organ of common sensation, it is by no means the only seat of the function: a variable but necessary share is possessed by the whole body, and accomplishes the general purpose of protection, perhaps also confers the muscular sense. Thus, by means of sensation, the injury of any particular part determines the occurrence of pain which is referred to that situation; and in this manner attention is directed to the seat of injury, and its duration or increase is prevented by a voluntary act. And it is probable that the sensitive branches which accompany the portio dura are of this kind; branches which, although very different in function, travel with the motor nerve, because they experience a distribution in its immediate neighbourhood. Indeed it is perhaps not unlikely that some of the sensory filaments which are included in the facial may bear a protective relation to this important nerve itself, possibly by a virtual distribution among its fibres: — a notion which would thus far approximate to the supposed "nervi nervorum" of the old authors.

But although the sensibility of the facial nerve is well ascertained, the origin or immediate cause of this endowment is still a matter of considerable dispute. The numerous views adopted by different authors offer many slighter modifications, but they are all reducible to two chief theories. One of these considers that the facial nerve is insensible at its origin from the brain; and that whatever amount of sensibility it subsequently exhibits is due to foreign filaments, which come from the acknowledged sensitive nerves of the fifth and pneumogastric; and which, joining the portio dura in different parts of its course, accompany it beyond these points included in its substance. The other regards the facial nerve as arising by two roots, whereof the larger is motor, the smaller sensitive; and that the sensibility of the nerve as a whole is the result of its double constitution, and is effected by its own sensory filaments.

Each of these theories has received the sanction of distinguished anatomists. Thus, amongst many others, the first has obtained the support of Magendie, Cruveilhier, Eschricht, Lund, &c.; while the latter numbers amongst its advocates, Arnold, Bischoff, Goedechens, Barthold, and, more lately, Morganti.

The dispute scarcely involves *the function*

* Lehrbuch der Physiologie, B. ii. S. 673.
† Muller's Archiv. 1844. Heft. 3, 4.

of the portio dura in that larger sense, in which we generally use this word of nerves; and hence the changes effected by disease afford very little aid to the settlement of the question. The inquiry therefore limits itself to a judgment on the two remaining kinds of evidence: firstly, the results of experiment; and secondly, the anatomical appearances. With this latter means of proof, a third is intimately associated in the present instance; viz. the analogies offered by the structure of the facial to other nerves, of which the functions are better ascertained. These analogies, where present, will argue a similarity of function; and in a degree of probability varying with the degree of the resemblance.

On the supposition that the sensory filaments are borrowed from neighbouring nerves, the very numerous junctions of the facial and fifth would naturally point to the latter as constituting one of the most probable and important sources. There are two ways of instituting the question experimentally. If these filaments come from this nerve, the destruction of its continuity will annihilate the sensibility alike of the facial and itself. Again, if the portio dura be insensible until joined by these branches of the fifth, irritation or section of the former nerve, previous to the point of junction, ought to be unattended by pain. In both these methods, the fifth is functionally separated from the facial; but in the second instance, the natural isolation of this nerve behind the situations where the fifth joins it, supplies the place of the artificial isolation practised in the first. And in both the continuance of sensibility would imply that the portio dura possessed inherent sensitive fibres.

The division of the fifth nerve within the skull, or close to its origin from the encephalon, has been attended with insensibility of the facial, in the hands of Magendie*, Eschricht, Lund †, and Longet ‡; and I am not aware of any such experiments which have contradicted their statements. The latter author states that, under these circumstances, the insensibility of the portio dura is perfect; but Lund and Eschricht, although they seem to deduce the same conclusion that he does, viz. that the sensibility of the facial nerve is entirely due to its anastomoses with the fifth, —yet, nevertheless, distinctly state that in their experiments the insensibility produced extended only from the ear forwards; while behind this situation the portio dura still evinced a well-marked sensibility. Apparently, Longet would explain this contradiction by supposing that the nerve behind the ear, which they found to be still sensible, was an ascending filament of the cervical plexus; but it seems very unlikely that they should confound the facial trunk with so very small a twig as one of these cervical branches would be. It must be observed that the results afforded by section of the fifth are only valid when the whole of the nerve has been divided, since in any other case there is a possibility that the sensibility of the facial, which remains after the operation, is due to the reception of filaments from the uncut branches.

These anatomical considerations apply even more forcibly to the second series of experiments. Thus, in some of them, conclusions are sought to be drawn from the observed sensibility of the larger branches of the nerve in the face; but the numerous anastomoses with the fifth, of which mention has previously been made, and especially that large union with the auriculo-temporal nerve of its third division, immediately in front of the ear, invalidate all these results.

Similar contradictory evidence obtains concerning the sensibility of the facial at its emergence from the skull, or behind its more visible junctions with the fifth. Thus, Valentin regards it as insensible in this place, while the experiments of Longet, Morganti (and probably Eschricht and Lund, as above stated), induce them to maintain the opposite opinion. So that, perhaps, on the whole, the balance of evidence inclines towards the statement that the irritation of the facial nerve at the stylo-mastoid foramen is attended with expressions of pain, and, therefore, that the nerve is possessed of sensibility at this place.

The reception of this fact considerably narrows the question; since the only branches connected with the facial above this point are, the greater and lesser superficial petrosal nerves, and the auricular filament of the pneumogastric. But Morganti has laid bare the chorda tympani in the tympanum, and has proved its sensibility to irritation. And this nerve, it will be recollected, comes* from the portio dura at a point above its junction with the auricular filament; and since the latter is thus not essential to the sensibility of this branch of the facial, so in all probability it is not necessary to the sensibility of this trunk itself. Thus the superficial petrosal nerves only remain; and many who consider one or both of these to join the facial, explain the sensibility of the nerve in the Fallopian canal by supposing that they convey to it branches of the second or third division of the fifth, which pass through the spheno-palatine and otic ganglia respectively. But, as has been previously stated, anatomy fails to recognise such a direct passage to the facial; and, on the contrary, by showing the unequivocally ganglionic nature of the genuform intumescence, renders it highly improbable. And on physiological grounds, it seems difficult to imagine that a nerve or nerves should pass unchanged through two successive nervous

* Leçons sur les Fonctions du Système Nerveux, tom. ii. p. 181.

† Dictionnaire des Sciences Médic., Journal Complém, tom. xxvi. p. 204.

‡ Loc. cit.

* Some have supposed the chorda tympani to pass from the gustatory to the facial nerve, conveying sensitive fibres to it. But numerous arguments, especially its anatomy and function as above mentioned, combine to render this supposition quite untenable.

centres, of which they form such large and important roots: while, allowing them to be affected in their functions, we are at least not justified in calling them "sensitive branches of the fifth."

By this elision of one sensitive anastomosis after another, sensibility still remaining, we have been led, in a retrograde course, to the ganglion at the hiatus Fallopii: at and above this point the evidence afforded by experiment fails us.

Magendie* states himself to have succeeded, in one instance, in exposing the facial nerve within the skull, or where it enters the auditory meatus; and adds that it was insensible to irritation. But the experiment stands alone, and it appears doubtful whether the portio intermedia was included in the irritation.

But the anatomical discoveries of Morganti may somewhat supply the deficiency of direct evidence. He has pointed out the complete analogy of the facial to a spinal nerve; and hence deduces the probability, that the portio intermedia, which exclusively forms the geniculate ganglion, is, like the posterior or gangliform root of the spinal nerve, the source of sensitive fibres to the compound nerve.

The observed insensibility of the facial after section of the fifth militates strongly against this view. But it will be recollected that although affirmed by some, it has been denied by others. And even granting it to be as complete as Longet states it, yet possibly it would constitute a less conclusive objection than might at first appear. For when we consider the violent nervous shock which division of the important trifacial must produce on the parts in the immediate neighbourhood of its origin, and the close proximity of the two nerves at their roots, we are perhaps justified in considering the result an insufficient testimony to their more immediate connection. A comparison of the lesion and symptoms in many cases of cerebral hemorrhage would almost parallel the occurrences of such an anæsthesia; while, in such an instance, a direct continuity would scarcely be admitted.

But even granting that the facial nerve, as thus constituted, possesses an inherent sensibility, it is still probable, from its numerous anastomoses, both with the fifth and with the cervical nerves, that it subsequently receives many additional sensory filaments. These junctions differ from a plexus like the cervical, or brachial, in the fact that, in place of forming communications between the mixed nerves of different segments of the body, they connect nerves of different endowments. The exchange appears to be at the expense of the sensitive nerve; that is, more filaments seem to pass from the fifth to the facial than from the latter to the former. The amount of these filaments given to the different branches of the seventh is said to differ: thus, Longet affirms the insensibility of the "mentonnier," or supra-maxillary portion.

* Loc. cit.

Little can here be said of the more minute ramifications of Morganti's theory.* But nothing that is known at present, either of the facial generally, or of the chorda tympani, or superficial petrosal branches, is absolutely incompatible with his views. All of these branches, except the lesser petrosal, he shows to be mixed nerves: the experiments and observations above quoted tend to indicate all as more or less directly subservient to motion; and in none are we able to deny the possibility of sensation. But the petrosal nerves would probably be likened to the branches which connect the roots of the spinal nerves to the sympathetic ganglia on the side of the spine; and the obscure and uncertain results obtained by experiment on these filaments of the facial are closely analogous to the effects of similar experiments on the spinal nerves in connection with the sympathetic of the trunk. But the anomaly of the tensor tympani being apparently supplied solely from the sensitive portion of the facial nerve, is very much weakened by the physiological facts of the involuntary character of its movements, and the interposition of a second ganglion.

The more important effects of disease of the facial nerve have already been spoken of in treating of its functions. For its morbid anatomy, in which it offers no especial peculiarity, reference is made to the article Nerve.

Bibliography. *See* Nervous System.

(*William Brinton.*)

SHELL.—This term is commonly employed to designate the hard envelopes in which the bodies and members of many animals belonging to the Radiated, Molluscous, and Articulated sub-kingdoms are enclosed. Generally speaking, it is applied to those only into whose composition mineral matter enters: thus, we speak of the shell of a Crustacean, whilst we do not give that appellation to the dermo-skeleton of an Insect or Myriapod. Still this rule is not strictly observed; for there are many Crustacea and Mollusca which are commonly spoken of as possessing shells although these bodies are entirely destitute of calcareous matter, being as horny in their texture as the envelope of a beetle or a centipede. Among *radiated* animals, the class of Echinodermata is the only one in which shells are met with; and these are by no means universally present throughout the group. In the *molluscous* series, we meet with shells in every class save the Tunicata; *all* the animals of the class Conchifera, whether *lamelli-branchiate* or *pallio-branchiate*, being furnished with them; a considerable proportion of Gasteropoda (*all* of them, it would seem, in the embryonic state) possessing them;

* The comparative anatomy of the geniculate ganglion seems to show that its position is much more closely related to the orifice of the bone than to the motor nerve. Is this any analogy to the similar close relation (to a more external aperture) of the ganglion on the posterior root of a spinal nerve?

whilst they are occasionally found in the delicate little PTEROPODA, and in the comparatively gigantic CEPHALOPODA. In this last class, however, the shells are not unfrequently *internal;* an approach to this arrangement being seen in certain Gasteropoda and Pteropoda, in which the shells are covered-in by folds of the mantle, whilst really external to the body. In the *articulated* series, the presence of a shelly covering, according to the usual acceptation of the term, is more restricted. It is possessed by a few ANNELIDA (e. g. *Serpula*, *Spirorbis*, &c.), whose shelly tubes so much resemble those of certain Mollusks as to be readily confounded with them. It is usually found, too, in the CIRRHOPODA, (a class whose articulated character is now quite settled); and it is generally present in the CRUSTACEA, although it is only in the larger and more highly developed forms of this class, that the shell is consolidated by mineral deposit, and really deserves the appellation.

The external configuration of the principal varieties of shelly covering having been sufficiently described under the several heads above referred to, it is not requisite here to revert to that subject; our present purpose being to give an account of the *intimate structure* of shell, on which an entirely new light has been thrown by microscopical enquiries. The prevalent doctrine respecting the nature of shell, as expressed even by the most recent conchological writers, has been that it is not only *extravascular*, but completely *inorganic*, being composed of an *exudation* of calcareous particles, cemented together by animal glue. It may now, however, be stated as an ascertained fact, that shell always possesses a more or less distinct organic structure* ; this being in some instances of the character of that of the *epidermis* of higher animals, but in others having more resemblance to that of the *dermis*, or true skin. The nature of the organic structure is so entirely different in the Mollusca, Echinodermata, and Crustacea respectively, that a separate description is required for each; indeed, even in the subordinate divisions of these groups very characteristic diversities are frequently observable; so that, as in the case of teeth, it is often possible to determine the family, sometimes the genus, and occasionally even the species, from the inspection of a minute fragment of a shell, as well fossil as recent; whilst the degree of correspondence or difference in the intimate structure appears to be, in many groups, more valuable than any other single character as a basis for classification, because more indicative of the general organisation of the animal. Examples of both these applications will be presently given.

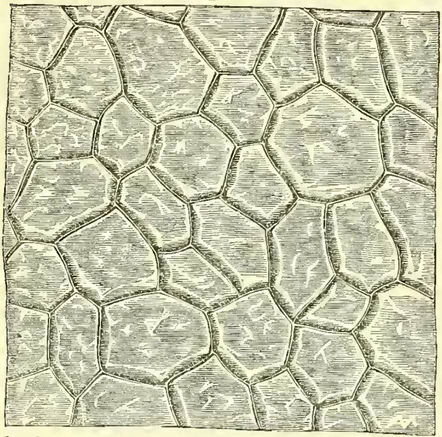
Mollusca.— The shells of Mollusca may always be regarded as *epidermic* in their character; being formed upon the surface of the mantle, which answers to the true skin of other animals. As might be anticipated from this description, they are essentially composed of *cells*, consolidated by a deposit of carbonate of lime in their interior; but, as in other tissues, we frequently find that the original cellular organisation is obscured by subsequent changes, and we sometimes lose all traces of it. We shall first examine it in what may be considered its typical condition, which is most characteristically seen in certain bivalves.

If a small portion be broken away from the thin margin of the shell of any species of *Pinna*, (this margin being composed of the *outer* layer only, which projects beyond the inner), and it be placed without any preparation under a low magnifying power, it presents on each of its surfaces, when viewed by transmitted light, very much the appearance of a honeycomb; whilst at the broken edge it exhibits an aspect which is evidently fibrous to the eye, but which, when examined under the miscroscope with reflected light, resembles that of an assemblage of basaltic columns. The shell is thus seen to be composed of a vast number of prisms, having a tolerably uniform size, and usually presenting an approach to the hexagonal shape. These are arranged perpendicularly (or nearly so) to the surface of the lamina of the shell; so that its thickness is formed by their length, and its two surfaces by their extremities. A more satisfactory view of these prisms is obtained by grinding down a lamina until it possesses a high degree of transparency; and it is then seen (*fig.* 407.) that the prisms themselves appear to be composed of a very homogeneous substance, but that they are separated by definite and strongly-marked lines of division. When such a lamina is submitted to the action of dilute acid, so as to dissolve away the carbonate of lime, a tolerably firm and consistent membrane is left, which exhibits the prismatic structure just as perfectly as did the original shell (*fig.* 408.); the hexagonal divisions being evidently the walls of cells resembling those of the pith or bark of a plant, in which the cells are frequently hexagonal prisms. In very thin natural laminæ, the nuclei of the cells can often be plainly distinguished; but we cannot expect to find these, when the two ends of the cells (at one of which they are generally situated) have been removed by grinding. By making a section of the shell perpendicularly to its surface, we obtain a view of the prisms cut

* The idea that such would prove to be the case was expressed by the author of this article in the 2d edition of his "Principles of General and Comparative Physiology" (published in 1841), as follows:—"The dense calcareous shells of the Mollusca, and the thinner jointed envelopes of the Crustacea, have been commonly regarded as mere exudations of stony matter, mixed with an animal glue secreted from the membrane which answers to the true skin. The hard axes and sheaths of the Polypifera, however, have been also regarded in the same light; and yet, as will hereafter appear, these are unquestionably formed by the consolidation of what was once living tissue. From the analogy which the shells of Mollusca and Crustacea bear to the epidermic appendages of higher animals, there would seem reason to believe that the former, like the latter, have their origin in cells, and that these are afterwards hardened by the deposition of earthy matter in their interior." P. 33.

in the direction of their length (*fig.* 409.); and it is then seen that whilst many of them pass

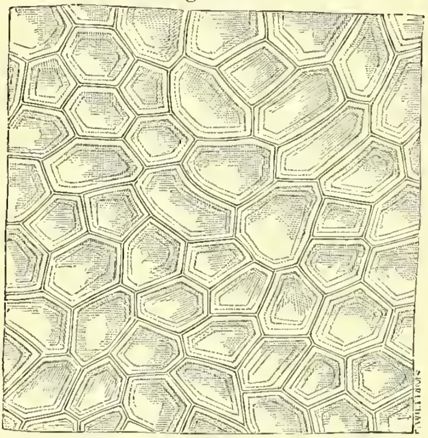
Fig. 407.



Section of the shell of Pinna parallel to the surface, showing prismatic cellular structure, cut transversely. Magnified 185 *diameters.*

continuously from one surface of the layer to the other, some terminate in points midway.

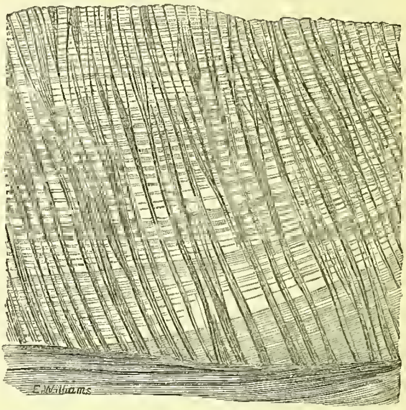
Fig. 408.



Lamina of decalcified membrane of prismatic cellular structure, from shell of Pinna. Magnified 185 *diameters.*

Hence it happens that the *number* of the reticulations is smaller on the interior than on the exterior of the layer; their *size*, on the contrary, being greater. The prisms are seen to be marked by delicate transverse striæ, closely resembling those observable on the prisms of the enamel of teeth, to which this kind of shell-structure may be considered as bearing a very close resemblance, except as regards the mineralising ingredient. If a similar section be decalcified by dilute acid, the membranous residuum will exhibit the walls of the prismatic cells viewed longitudinally; and these will be seen to be more or less regularly marked by the transverse striæ just alluded to. It sometimes happens in recent, but still more commonly in fossil shells, that the decay of the animal membrane leaves the contained prisms without any con-

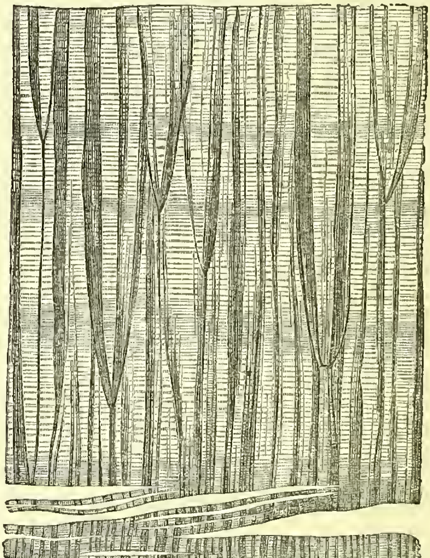
Fig. 409.



Vertical section of prismatic cellular structure, from external layer of shell of Unio occidens. Magnified 40 *diameters.*

necting medium; and being then quite isolated, they can be easily detached from one

Fig. 410.

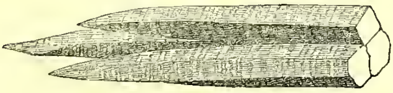


Vertical section of cellular structure of Pinna; at its lower part the membrane is splitting into thin layers. Magnified 74 *diameters.*

another without any fracture. A group of three such prisms, found in a fragment of chalk, is shown in *fig.* 411.: it is seen that these also exhibit transverse striæ of a similar aspect. By submitting the edges of the membranous walls of the prismatic cells divided longitudinally (as in *fig.* 410.) to a high magnifying power, the cause of the transverse

striation is seen to be a thickening of the cell-wall in those situations; which will of course

Fig. 411.



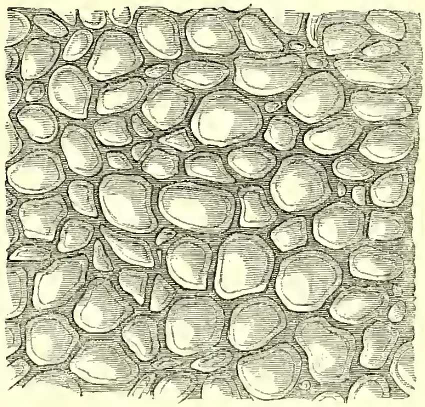
Calcareous prisms of the shell of Pinna; from Chalk.

produce a corresponding series of indentations upon the contained prisms. This thickening seems best accounted for by supposing (as first suggested by Prof. Owen) that each long prismatic cell is made up by the coalescence of a pile of flat epidermic cells, the transverse striation marking their lines of junction; and this view corresponds well with the fact that the shell-membrane not unfrequently shows a tendency to split into thin laminæ along the lines of striation, as shown in the lower part of *fig.* 410; whilst we occasionally meet with an excessively thin natural lamina, composed of flat pavement-like cells resembling those of the epithelium of serous membrane, lying between the thicker prismatic layers, with one of which it would have probably coalesced but for some accidental cause which preserved its distinctness. That the entire length of the prism is not formed at once, but that it is progressively lengthened and consolidated at its lower extremity, would appear also from the fact that where the shell presents a deep colour (as in *Pinna nigrina*) this colour is usually disposed in distinct strata, the outer portion of each layer being the part most deeply tinged, whilst the inner extremities of the prisms are almost colourless.

The prismatic arrangement of the carbonate of lime in the shells of *Pinna* and its allies has been long familiar to conchologists; but it has been usually regarded as the result of crystallisation. It is now, however, perfectly evident that the calcareous prisms are nothing else than *casts* of the interior of the prismatic cells; the form of which, however irregular, they constantly present; whilst the markings of the membrane are faithfully transferred to the surface of the prism. Further, the prisms in a thick layer of shell frequently present a decided curvature, which would not be the case if their form were due to crystallisation. Not unfrequently, moreover, they are altogether destitute of angular boundaries; the large quantity of animal matter disposed between the contiguous cells giving them a rounded contour, as seen in *fig.* 412, and thus causing the calcareous casts of their interior to be cylindrical rather than prismatic.

It is only in a few families of Bivalves, however, that the cellular structure is seen in this very distinct form, or that it makes up a large part of the substance of the shell; and these families are for the most part nearly allied to *Pinna*. In all the genera of the *Margaritaceæ*, we find the external layer of the shell formed upon this plan, and of considerable thickness; the internal layer being nacreous. In the *Unionidæ*, on the contrary, nearly the whole thickness of the shell is made up of the internal or nacreous layer; but a uniform stratum

Fig. 412.



Lamina of outer layer of shell of Ostrea edulis, showing its cellular structure, with a large amount of intercellular substance. Magnified 250 diameters.

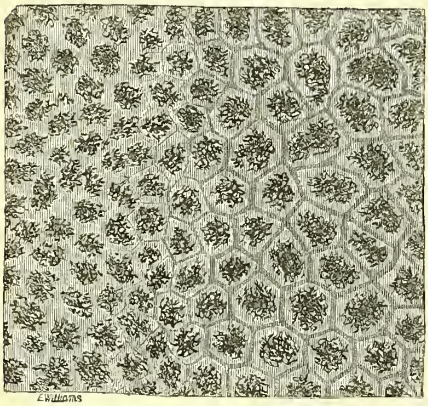
of prismatic cellular substance is always found between the nacre and the periostracum. In the *Ostraceæ* the greater part of the shell is composed of a sub-nacreous substance, the successively-formed laminæ of which have very little adhesion to each other; but every one of these laminæ is bordered at its free edge by a layer of the prismatic cellular substance, distinguished by its brownish-yellow colour: this structure presents itself again in the family *Pandoridæ*, which belongs to quite a different section of the class; and it is curious to observe that the marked difference in the structure of the shells of *Pandora* and *Lyonsia* from that of the *Anatinidæ* and other neighbouring families, harmonises completely with the peculiar combination of characters presented by the animals of these two genera.* In all the foregoing cases, a distinct cellulo-membranous residuum is left after the decalcification of the prismatic substance by dilute acid; and this is most tenacious and substantial where, as in the *Margaritaceæ*, there is no proper periostracum, — as if the horny matter which would have otherwise gone to form this investment had been diffused as an intercellular substance between the proper cell-walls.

In many other instances, a cellular arrangement is perfectly evident in sections of the shell; and yet no corresponding structure can be distinctly seen in the delicate membrane left after decalcification. In all such cases, the animal basis bears but a very small proportion to the calcareous deposit, and the shell is usually extremely hard. A very characteristic example of this is presented by the outer layers of the shells of the genus *Thracia* and other *Anatinidæ*. But there are numerous other cases, in which no traces of cellular structure can be detected in the fully-formed shell, and in which we can only be guided by analogy in

* See Forbes and Hanley's British Mollusca, vol. i. pp. 207, 213.

assigning to them a similar origin with the preceding. We seem justified in doing so, however, by two considerations. In the first place, where the fully-formed shell is destitute of cellular arrangement, this may be frequently detected in the embryonic shell; as the author is informed by Dr. Leidy of Philadelphia, who has carefully studied the embryology of many Mollusca. And secondly, there are certain shells which exhibit so complete and gradual a transition from a distinct cellular arrangement to an apparently homogenous structure, that we can scarcely doubt the common origin of both substances. This is particularly well seen in the common *Mya arenaria*, a careful examination of which shell brings to light numerous interesting varieties of cellular organisation. Thus in *fig.* 413. we see in one part of

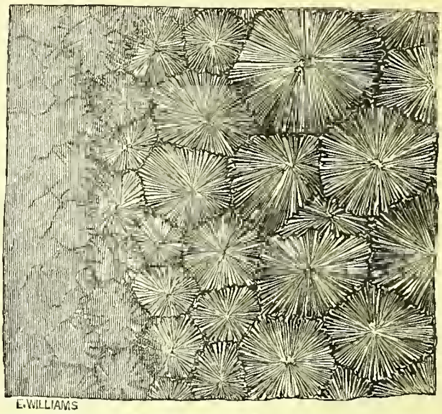
Fig. 413.



Section of shell of Mya arenaria, showing in one part distinct cellular partitions, with large nuclear spots; whilst in another part of the same layer, the cell-boundaries become fainter, and then disappear altogether. Magnified 150 *diameters.*

the section a very distinct set of cell-boundaries, with a large nuclear spot in the centre of each cell; whilst on the other side we observe that the cell-walls have completely disappeared,—the nuclear spots, however, still remaining to mark the cellular origin of the substance. A little further on, these also might disappear, and thus all traces of the original organisation might be lost, though no reasonable doubt could be entertained as to its prior existence. A very curious variety of cell-structure is seen in the large hinge-tooth of Mya, in which there is a layer of large cells occupied by carbonate of lime disposed in a radiated form of crystallisation, resembling that of the mineral called Wavellite. Approaches to this beautiful arrangement may be seen in many other shells. Here, too, we find the partitions between the cells gradually becoming less distinct, as we pass from this peculiar stratum into the surrounding substance, until we lose them altogether. In general, a cellular layer may be detected upon the external surface of bivalve shells, where this has been protected by a periostracum, or has been prevented in any other mode from undergoing abrasion: thus it is found occasionally in *Anomia* and *Pecten*, and generally in *Chama, Cleidothærus,*

Fig. 414.



Section of the hinge-tooth of Mya arenaria, showing radiating arrangement of carbonate of lime within the cells, and the gradual disappearance of the cell-boundaries, so that the texture becomes homogeneous. Magnified 80 *diameters.*

Trigonia, *Anatina*, *Solen*, *Glycimeris*, *Solemya*, &c. In the last-named genus it is very firm, and leaves a distinct membranous residuum after the calcareous matter has been removed by acid, which is not the case with the others. The cells of which the outer layer of the shell is made up are frequently rather *fusiform* than prismatic in their shape, and are disposed with their long axes nearly parallel to its surface, so that their extremities "crop out" very obliquely on its exterior, where their rounded terminations, containing nuclei, may often be distinguished when the surface has not suffered abrasion. (See *fig.* 416.)

The internal layer of Bivalve shells rarely presents a distinct cellular structure, when examined in a thin section; and the residuum left after decalcification is usually a distinct but structureless membrane, closely resembling the "basement membrane" of Mr. Bowman. (Mucous Membrane.) This form of shell-substance may consequently be distinguished as *membranous*. In the *Margaritaceæ* and many other families, this internal layer has a nacreous or iridescent lustre, which depends (as Sir D. Brewster has shown*) upon the striation of its surface with a series of grooved lines, which usually run nearly parallel to each other. As these lines are not obliterated by any amount of polishing, it is evident that their presence depends upon something peculiar in the texture of this substance, and not upon any mere superficial arrangement. When a piece of nacre is carefully examined, it becomes evident that the lines are produced by the cropping-out of laminæ of shell situated more or less obliquely to the plane of the surface. The greater the *dip* of these laminæ, the closer will their edges be; whilst the less the angle which they make with the surface,

* Phil. Trans. 1814.

the wider will be the interval between the lines. When the section passes for any distance in the plane of a lamina, no lines will present themselves on that space. And thus the appearance of a section of nacre is such as to have been aptly compared by Sir J. Herschel* to the surface of a smoothed deal board, in which the woody layers are cut perpendicularly to their surface in one part, and nearly in their plane in another. Sir D. Brewster appears to suppose † that nacre consists of a multitude of layers of carbonate of lime alternating with animal membrane; and that the presence of the grooved lines on the most highly-polished surface is due to the wearing away of the edges of the animal laminæ, whilst those of the hard calcareous laminæ stand out. If each line upon the nacreous surface, however, indicate a distinct layer of shell-substance, a very thin section of mother-of-pearl ought to contain many thousand laminæ, in accordance with the number of lines upon its surface; these being frequently no more than 1-7500th of an inch apart. But when the nacre is treated with dilute acid, so as to dissolve its calcareous portion, no such repetition of membranous layers is to be found: on the contrary, if the piece of nacre be the product of one act of shell-formation, there is but a single layer of membrane. The membrane is usually found to present a more or less *folded* or *plaited* arrangement; but this has generally been obviously disturbed by the disengagement of carbonic acid in the act of decalcification, which tends to unfold the plaits. There is one shell, however, — the well-known *Haliotis splendens*,—which affords us the opportunity of examining the plaits *in situ*, and thus presents a clear demonstration of the real structure of nacre. This shell is for the most part made up of a series of plates of animal matter, resembling tortoise-shell in its aspect, alternating with thin layers of nacre; and if a piece of it be submitted to the action of dilute acid, the calcareous portion of the nacreous layers being dissolved away, the plates of animal matter fall apart, each one carrying with it the membranous residuum of the layer of nacre that was applied to its inner surface. It will usually be found that the nacre-membrane covering some of these horny plates will remain in an undisturbed condition; and *their surfaces then exhibit their iridescent lustre, although all the calcareous matter has been removed from their structure.* On looking at the surface with reflected light under a magnifying power of 75 diameters, it is seen to present a series of folds or plaits more or less regular; and the iridescent hues which these exhibit are often of the most gorgeous description. But if the membrane be extended with a pair of needles, these plaits are unfolded, and it covers a much larger surface than before; and the iridescence is then completely destroyed. This experiment, then, demonstrates that the peculiar lineation of the surface of nacre (on which the iridescence undoubtedly depends, as first shown by Sir D. Brewster), is due, not to the outcropping of alternate layers of membranous and calcareous matter, but to the disposition of a single membranous layer in folds or plaits, which lie more or less obliquely to the general surface.

* Edinb. Philos. Journ. vol. ii.

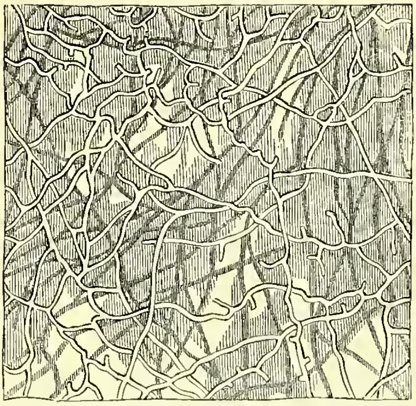
† Loc. cit.

There are several bivalve shells which present what may be termed a *sub-nacreous* structure, their polished surfaces being covered with lines indicative of folds in the basement membrane; but these folds are destitute of that regularity of arrangement which is necessary to produce the iridescent lustre. This is the case, for example, with most of the *Pectinidæ*, also with some of the *Mytilaceæ*, and with the common *Oyster*. Where there is no indication of a regular corrugation of the shell-membrane, there is not the least approach to the nacreous aspect; and this is the case with the internal layer of by far the greater number of shells, the presence of nacre being exceptional, save in a small number of families.

The membranous shell-substance, some form of which constitutes the internal layer of most bivalve shells, is occasionally traversed by tubes, which seem to commence from the inner surface of the shell, and to pass towards the exterior. These tubes vary in size from about the 1-20,000th of an inch, or even less, to about the 1-2000th; but their general diameter, in the shells in which they most abound, is about 1-4000th of an inch. The direction and distribution of these tubes are extremely various in different genera. Thus, in *Anomia Ephippium* they are scantily distributed in the internal nacreous lamina; but in the yellow outer layer they are very abundant (*fig.* 415.), forming an irregular net-work, which spreads out in a plane parallel to the surface. In *Cleidothærus chamoides*, on the other hand, the tubes are abundant in the internal layer of the nacreous lining, where they form an intricate but irregular net-work parallel to the internal surface of the shell; and from this arise a series of straight tubes, which pass nearly at right angles with the surface, at a considerable distance from each other, through the external portion of the nacreous layer, towards the cellular structure which constitutes the exterior of the shell. This, however, they do not penetrate; stopping short as they approach it, just as the tubes of dentine cease at its plane of junction with the enamel. The diameter of the tubes is tolerably uniform, even when they divaricate; the trunk not being much larger than either of the branches. In other instances, however, no such net-work is formed, but the tubes run at a distance from each other, traversing the shelly layers obliquely, and are then usually of comparatively large size: this is the case, for example, with some species of *Arca* and *Pectunculus*. That these tubes are not mere channels or excavations in the shell-substance, is proved by the fact that they may be frequently seen very distinctly in the decalcified shell-membrane. They often present, in their beaded aspect, indications of a cellular origin, as if they had been formed

by the coalescence of a series of cells arranged in a linear direction. They are generally most abundant in shells whose exterior has a foliated or sculptured character; and not unfrequently they may be distinctly seen to pass directly towards the prominences of the surface, — as in *Lima scabra* and various species of *Chama*. They are by no means restricted, however, to shells thus characterised; nor are they universally present in them.

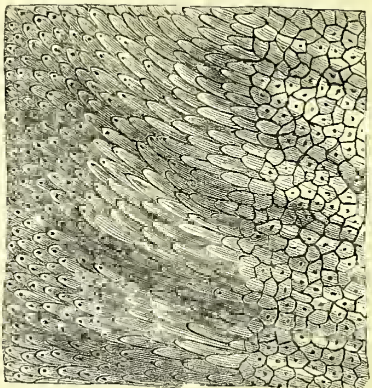
Fig. 415.



Tubular shell-structure from external surface of Anomia Ephippium. Magnified 250 *diameters.*

Of the origin and mode of formation of the membranous shell-structure, it is rather difficult to give an exact account. Possibly, after the epidermic cells have undergone calcification, so as to form the external cellular layer, the basement membrane itself may become detached from the surface of the mantle, in combination with a layer of calcareous matter. Even in nacre, however, which may be considered as the most perfect form of this substance, indications of cellular structure are not unfrequently to be seen, especially in univalve shells: these are particularly evident in *Haliotis*, the nacreous laminæ of which, when carefully examined under a sufficiently high magnifying power, are found to be composed of minute cells of a long oval form (*fig.* 416.), their short diameter not being above 1-5000th of an inch. Their boundaries in many parts are very indistinct, or even disappear altogether, so that every gradation can be traced, from the obviously cellular arrangement shown in *fig.* 412., to the homogeneous aspect presented by the nacre of bivalve shells. The same cellular structure, and the same gradation to a homogeneous stratum, may be made apparent in the decalcified membrane; so that here we seem to have evidence that even the membranous shell-substance is originally formed by the agency of cells, although the boundaries of these have usually been subsequently obliterated, so that the structure comes to present a homogeneous aspect. Indications of the same cellular organisation may be detected in the nacreous lining of the shell in *Turbo* and *Nautilus*. We seem justified in concluding that nacre has everywhere a similar origin; and if one variety of membranous shell-substance be thus

Fig. 416.



Cellular structure of nacre of Haliotis splendens: the cells cut transversely at *a*, longitudinally at *b*, and showing their terminations (with nuclear spots) at *c*. *Magnified* 450 *diameters.*

proved to have been formed by the agency of cells, little doubt can be entertained as to the corresponding organisation of others. The fact may probably be, that, as maintained by Professor Goodsir *, the basement membrane is itself composed of cells more or less perfectly developed, the boundaries of which usually disappear. Of this view a very good illustration is afforded by the various examples of shell-membrane; which present every gradation, from the most perfectly homogeneous pellicle, to a distinct stratum of cells.

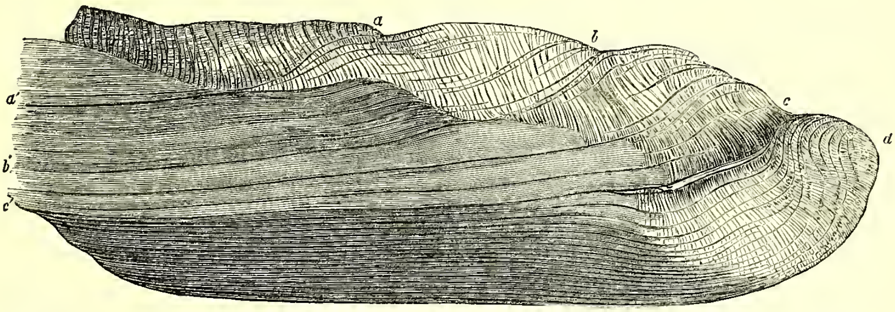
The loss of the original boundaries of the cells, and the consequent obscuration of the real nature of the structure, are by no means peculiar to shell; for the physiologist is familiar with this change as occurring in various other tissues. Thus, in dentine, the cases in which the vestiges of the original cells are preserved are few in proportion to those in which they are obliterated; and yet these isolated examples are sufficient to mark the real nature of the transformation of the soft dentinal pulp into the dense ivory. It would seem as if, in the process of calcification, the cell-walls have a tendency to liquefy or dissolve away, unless supported by additional deposits of animal matter, thus allowing the complete *fusion* of their contents. The peculiar tenacity of the decalcified shell-substance in the *Margaritaceæ* and certain other tribes seems due, not so much to the strength of the *original* cell-walls, as to the interposition of an intercellular substance between them. In *Perna* we not unfrequently find, between the calcified layers, membranous laminæ consisting chiefly of horny matter interposed between rounded cells that are more or less widely separated from each other: here the animal substance

* Anatomical and Pathological Observations, p. 3, *note*.

would seem to be peculiarly abundant, being apparently of the same kind as that of which the *byssus* of these animals is composed.

The ordinary account of the mode of growth of the shells of Bivalve Mollusca,—that they are progressively enlarged by the deposition of new laminæ, each of which is in contact with the internal surface of the preceding, and extends beyond it,—does not express the whole truth; for it takes no account of the fact that most shells are composed of two layers of very different texture, and does not specify whether *both* these layers are thus formed by the entire surface of the mantle whenever the shell has to be extended, or whether only *one* is produced. An examination of *fig.* 417. will clearly show the mode in which the operation is effected. This figure

Fig. 417.

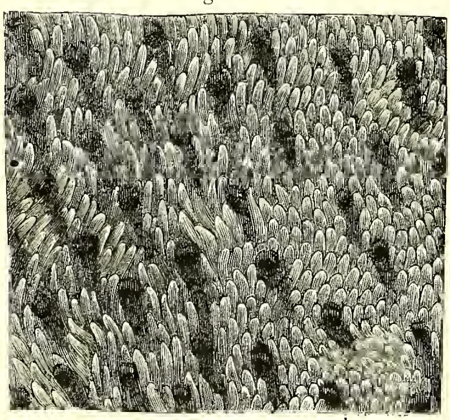


Vertical section of shell of Unio occidens, near the lip, showing the arrangement of the outer or prismatic, and the internal or nacreous layers: a a', b b', c c', successive lines of growth; *d*, margin of the valve *Magnified* 8 *diameters.*

represents a section of one of the valves of *Unio occidens*, taken perpendicularly to its surface, and passing from the margin (at the right hand of the figure) towards the umbo (which would be at some distance beyond the left). This section brings into view the two substances of which the shell is composed; traversing the outer or prismatic layer in the direction of the length of its cells, and passing through the nacreous lining, which is seen to be made up of numerous laminæ, separated by the lines *a a'*, *b b'*, *c c'*, &c. These lines evidently indicate the successive formations of this layer; and it may be easily shown, by tracing them towards the umbo on the one side, and towards the margin on the other, that at every enlargement of the shell its whole interior is lined by a new nacreous lamina, in immediate contact with that which preceded it. The number of such laminæ, therefore, in the oldest part of the shell, indicates the number of enlargements which it has undergone. The outer or prismatic layer of the growing shell, on the other hand, is only formed where the new structure projects beyond the margin of the old; and thus we do not find one layer of it overlapping another, except at the lines of junction of two distinct formations. When the shell has attained its full dimensions, however, new laminæ of both layers still continue to be added; and thus the lip becomes thickened by successive formations of prismatic structure, each being applied to the inner surface of the preceding, instead of to its free margin. The same arrangement may be well seen in the *Oyster;* with this difference, that the successive layers have but a comparatively slight adhesion to each other.

The shells of *Terebratulæ*, and of several other genera of *Brachiopoda*, or *Palliobranchiate* Bivalves, are distinguished by peculiarities of structure, which serve to distinguish them from all others. When thin sections of them are microscopically examined, they present a very peculiar texture, (*fig.* 418. *a.*)

Fig. 418.

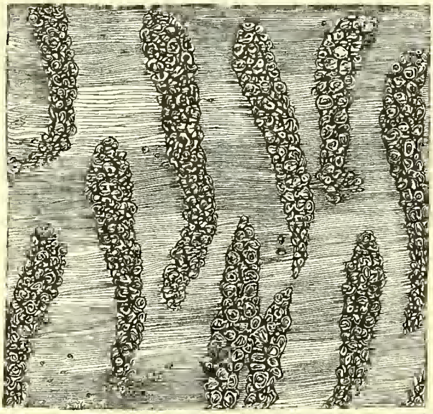


Portion of the shell of Terebratula australis, showing the orifices of the perforations, and the peculiar structure of the shell: at *a* the shell is traversed by the section; at *b* is shown its internal surface.

which might be referred either to long flattened cells, or to plications in the shell-membrane; on the other hand, the natural internal surface of these shells always exhibits an imbricated aspect of great regularity (*b*). If the section pass very obliquely towards this surface, it becomes evident that these imbrications are formed by the outcrop of the long flattened cells or folds, which were seen when the plane of the section has passed in the direction of

their length. A great variety of appearances is presented by this structure, according to the direction in which it happens to be traversed by the section; but they are all indicative of its peculiar character, which is readily recognisable even in the minutest fragment, although its nature yet remains doubtful. The cells, if cells they be, must be excessively flattened; and no vestige of them can be traced in the decalcified shell; whilst, on the other hand, the membranous residuum does not give any distinct indication of having been plicated with the regularity necessary to produce such a remarkable appearance. When any *recent* species of *Terebratula* is examined, save *Ter. psittacea* (which is now generally excluded from the genus on other grounds), an additional peculiarity is observed; consisting of the presence of a large number of *perforations* in the shell, generally passing obliquely from one surface to the other, and terminating internally by an open orifice (*fig.* 418.), whilst on the exterior they are covered in by the periostracum. Their diameter, which is greatest towards the external surface, varies in different species from about 1-1800th to 1-500th of an inch; and there is a considerable difference, also, in their degree of proximity to each other. In some fossil species, as *Ter. bullata*, the interval between the passages is scarcely greater than the diameter of the passages themselves. When a portion of one of these shells, which has been preserved with the animal in spirit, has been completely decalcified by the action of dilute acid, the membranous residuum presents a very remarkable structure, no vestige of which is seen in the ordinary bivalves. Attached to the membranous films are a series of tubular appendages, corresponding in diameter to the perforations of the shell, and arranged at the same distances (*fig.* 419.): the free extremities of these appendages have distinct cœcal terminations; and when a sufficient magnifying power is employed, it is found that their contents are distinctly cellular, resembling the cells in the interior of glandular follicles. These cœcal tubuli lie in the perforations of the shell, and open on its inner surface; but there does not appear to be any system of tubes or canals for collecting the matter poured out from them, each cœcum having its distinct and independent termination on the internal surface of the shell. The surface of the mantle in contact with the shell is found to be studded with minute cells, corresponding in size and aspect with those contained in the cœcal tubuli. The physiological purpose of this curious structure is at present a mystery; but there can be little doubt that it is a very important one in the economy of the animal, when we see the shell thus rendered subservient to the special protection of the cœcal appendages. The perforations are wanting in a large proportion of the very numerous species of fossil *Terebratulæ*; and there would appear strong reason for regarding their presence or absence as a character of fundamental importance in the subdivision of this important genus.* In most of the non-perforated species, the shell is readily divisible into thin micaceous plates, which exhibit the characteristic texture of the shell in great perfection; and as this texture undergoes remarkably little change in the act of fossilisation, it is often possible to recognise a Terebratula from a very minute fragment, imbedded even in the palæozoic strata. A very similar structure exists in several genera allied to Terebratula; and in some of these, also, as *Orthis* and *Spirifer*, the distinction has to be established between the perforated and non-perforated species; whilst in *Atrypa* (to which the recent *Ter. psittacea* properly belongs), all the species are destitute of perforations.

Fig. 419.



Decalcified membrane of shell of Terebratula australis, showing the cœcal tubuli, which occupy the perforations of the shell: the tubuli are filled with minute cells. Magnified 150 *diameters.*

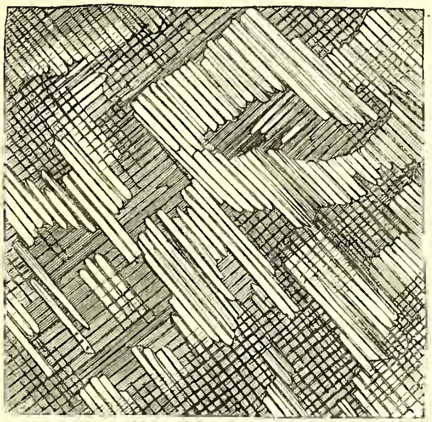
There is not, by any means, the same amount of diversity in the structure of the shell in the class of *Gasteropoda*, as that which exists among the several tribes of Conchifera; a certain typical plan of construction being common to by far the greater number of them. The small proportion of animal matter contained in most of these shells is a very marked feature in their character; and it serves to render other features indistinct, since the residuum left after the removal of the calcareous matter is usually so imperfect, as to give no clue whatever to the explanation of the appearances shown by sections. Nevertheless, the structure of these shells is by no means homogeneous, but always exhibits indications, more or less clear, of an original organic arrangement. The porcellanous shells, as formerly stated (vol. ii. p. 384), are composed of three layers, all presenting the same kind of structure, but each differing from the others in the mode in which this is arranged. This structure was described by Mr. Gray † as the result of rhomboidal crystallisation; each layer being com-

* See a Paper on the Subdivision of the Genus *Terebratula*, by Mr. J. Morris, in the Journal of the Geological Society, vol. ii. p. 382.

† Phil. Trans. 1833, p. 790.

posed of thin laminæ placed side by side, which separate from one another in the planes of cleavage when the shell is fractured. As first pointed out, however, by Mr. Bowerbank, each of these laminæ really consists of a series of cells in close apposition; and the plates are disposed alternately in contrary directions, so that each series of cells intersects the one beneath it nearly at right angles, as seen in *fig.* 420. Although the intimate structure of

Fig. 420.



ortion of fractured surface of middle layer of Cypræa mauritiana, showing laminæ composed of prismatic cells obliquely crossing one another. Magnified 235 *diameters.* (After Bowerbank.)

each of the three layers of the shell is essentially the same, yet the disposition of the laminæ is not the same in any two adjoining ones,—an arrangement which adds greatly to the strength of the shell. The planes of the laminæ are always as nearly as possible either parallel or at right angles to the lines of growth; those of the inner and outer layers always having the same direction with each other, but those of the middle layer being set at right angles to them. When, therefore, a section is made parallel to the surface of the shell, it will cut the *edges* of the laminæ of which the layers traversed by it are composed; but if the section be made in a direction perpendicular to the surface, and pass through the middle layer in the *plane* of its laminæ, it will cut through the *edges* of the laminæ making up the *interior* and *exterior* layers; whilst if the section traverse the two latter in the plane of their laminæ, it will cut across the laminæ of the middle layer.

The principal departures from this plan of structure are seen in *Patella*, *Chiton*, *Haliotis*, and *Turbo* and its allies. In *Patella*, the inner and outer layers are composed of large and irregular laminæ, by no means firmly adherent to one another; but the middle layer is made up of tolerably regular polygonal cells, which form only a thin stratum in some parts, whilst in others they are elongated into prismatic cells; and the directions of the laminæ, of which the inner and outer layers are composed, instead of being conformable with each other, are at right angles. In *Chiton*, the external layer, which seems to be of a delicate fibrous texture, but which is of extreme density, is perforated by large canals, which pass down obliquely into its substance, without penetrating, however, as far the middle layer. The middle layer, as in Patella, is distinctly cellular; whilst the internal has the same nearly-homogeneous texture as the external, but shows no trace of perforations. The peculiarities of structure presented by *Haliotis* have been already described. In *Turbo* and its allies, the inner layer is nacreous, and the middle one is made up of large cells: the cellular structure is also very evident in the solid operculum of Turbo, when reduced to sufficient thinness.

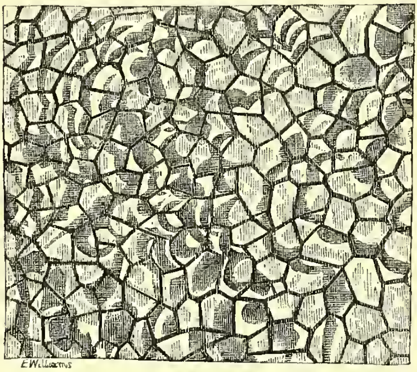
That the shell-substance in Gasteropoda is formed in the first instance by the agency of cells, however indistinct their traces may subsequently become, is further apparent from the researches of Mr. Bowerbank on the growth of the shell of the common garden-snail (*Helix aspersa*); and his observations further confirm the opinion already expressed, that the formation of each layer of shell is a progressive operation; new matter being added to its interior after the exterior has been consolidated.

Passing by the *Pteropoda*, whose delicate membranous shells present no very distinct structure, we come to the testaceous *Cephalopoda*, of which there are but few species now existing. The shell of *Nautilus pompilius* bears more resemblance to that of bivalves in its intimate structure, than to that of the Gasteropodous univalves; the three layers of perpendicular laminæ, so characteristic of the latter, not making their appearance here; and of the two layers of which the shell is composed, the inner one being nacreous, whilst the outer one is made up of an aggregation of cells of various sizes, those which are nearest the external surface being generally the largest. In the thin shell of *Argonauta*, the same kind of irregular cellular structure can be easily distinguished, as in the outer layer of the shell of *Nautilus;* but there would seem to be nothing comparable to the inner layer of the latter. The shell of *Spirula* must be considered to bear a greater resemblance, as regards its relation to the animal, to the *Sepiostaire* of the Cuttle-fish, than to the chambered shell of the Nautilus; although it so closely approximates the latter in its own conformation. This being the case, it is interesting to find that the intimate structure of the shell has a much greater resemblance to the Sepiostaire than would be supposed from its general aspect. For although its texture seems uniform, and its minute parts are composed of an aggregation of calcified cells, yet its surface is marked by sinuous lines, closely resembling those which are seen upon the transverse plates of the Sepiostaire; and these lines or bands project in such a degree, that they might be considered as rudiments of the vertical partitions

which connect these plates. The *Sepiostaire* having been formerly described in some detail (vol. i., p. 546), it will only be requisite here to mention, that the calcified layers which alternate with horny membranes to form the shallow cone or cup, exhibit a distinct cellular structure, when the section is made sufficiently thin; and that indications of a similar structure may also be perceived in the delicate and fragile plates which are arranged obliquely upon one another in the hollow of this cup. Few of the numerous fossil shells referable to this class have yet been examined; it may, however, be stated as an interesting result of microscopic observation, that the "spathose guard" of the *Belemnite* is thereby proved to be composed of long prismatic cells, radiating from the centre to the circumference; closely resembling in their general arrangement those of the massive tube of *Septaria gigantea*, the great sand-boring Teredo of Sumatra.

The structure of the shells of the testaceous *Annelida*, and of the pedunculate *Cirrhopoda*, does not essentially differ from that of Mollusca; but in most of the sessile Cirrhopods, such as the common *Balanus*, we find a *cancellated* structure or diploë intervening between the inner and outer plates of the shell (vol. i., p. 685). A less regular

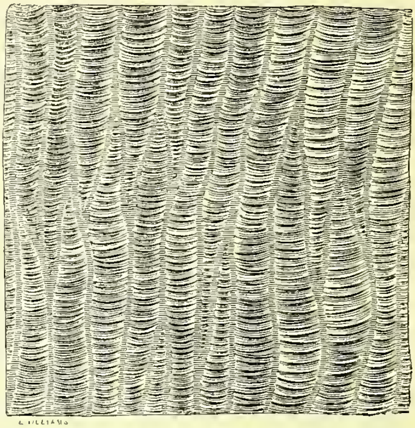
Fig. 421.



Cancellated structure from shell of Hippurite, as seen in transverse section. Magnified 5 diameters.

diploë has been described by Mr. J. E. Gray* as existing between the laminæ of *Ostrea purpurea;* but in no other shells of existing Mollusca has any approach to it been yet discovered. A very regular cancellated structure, however, is exhibited in the singular extinct group of *Rudistes*, where it makes up nearly the entire thickness of the shell (*fig.* 421.). The cancelli are usually short hexagonal prisms, terminated at each end by a flat partition; consequently, a section taken in one direction (*fig.* 421.) will exhibit the walls of the chambers disposed in a hexagonal network; whilst a section that passes at right angles to this will bring into view the transverse partitions (*fig.* 422.). The cancelli are frequently occupied by calcareous infiltration; which might lead to the belief that, like the cells of the Pinna, they were so consolidated in the living state. But they are also to be met with entirely empty, or with their walls merely lined by calcareous crystals; so that there can be no doubt that they were originally hollow. The presence of this structure assists in determining the zoological position of the curious group in question, which many considerations would lead us to regard as having been intermediate between the Bivalve Mollusca and the sessile Cirrhopoda. And it may be added that, by the same evidence, the place of the curious *Pleurorhyncus hibernicus*, a fossil which has been assigned to a different tribe by almost every naturalist who has examined it, would unhesitatingly be determined as amongst the Rudistes.

Fig. 422.



Cancellated structure from the shell of Hippurite, as seen in vertical section. Magnified 5 diameters.

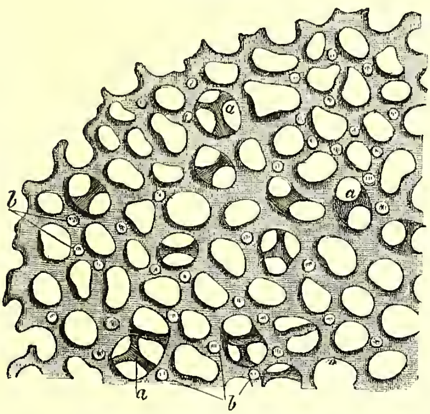
Echinodermata. — The structure of the skeleton in this class is entirely different from that which we have found to be characteristic of the Mollusca; whilst, in its essential features, it presents a remarkable uniformity throughout the various members of the group. The general arrangement of its components is the same, for example, in the firm plates which make up the testa of the *Echinida*, in the joints of the stems and branches of the *Crinoidea*, and in the scattered calcareous deposits which are met with in the integuments and in the tentacula of the *Holothurida*.

The elementary structure of the skeleton of the Echinodermata may be described as a *net-work*, composed of calcareous and animal matter intimately united; the former, however, being greatly predominant. In this net-work, the interspaces or *areolæ*, and the solid structure which surrounds them, may bear an extremely variable proportion to one another; so that, in two masses of equal size, the one or the other may greatly pre-

* Magazine of Zoology and Botany, vol. ii. p. 228.

dominate, and the texture may have either a remarkable lightness and porosity, or a considerable degree of compactness and brittleness. We may take the plates making up the shell of the Echinus as presenting a typical form of this structure; from which the transition is easy towards either the more solid or the more open character which it elsewhere presents. When we obtain a very thin slice of one of these plates, taken parallel to the surface of the shell, we find that it is composed of a lamina, apparently in itself destitute of structure, perforated with considerable regularity by apertures of a circular or oval form. The diameter of these apertures (*fig.* 423.) varies to a certain extent in

Fig. 423.



Thin Lamina of shell of Echinus, showing its areolar structure: a a, portions of subjacent layer; *b b,* fractured bases of columns connecting the superposed laminæ. *Magnified* 164 *diameters.*

different parts of the same shell, the reticulation being much coarser in the inner than in the outer layers: from numerous measurements, the extremes may be stated at about 1-450th and 1-2500th of an inch. The entire thickness of the shell is made up of an immense number of such plates, which lie parallel to each other, but not in contact; for they are separated from each other by little pillars, which rise up vertically from each plate to support the next, and which thus connect the different plates whilst holding them apart. The broken bases or ends of these minute pillars are commonly to be seen upon the surfaces of the perforated plates, at the spots intermediate between three or four of the apertures (*fig.* 423. *b*, *b*). The successive plates are always so disposed, that the centres of the perforations of one shall correspond with the intermediate solid structure of the next (*fig.* 423. *a*, *a*); and their transparency is such, that, when we have reduced a section to such a degree of thinness as to contain a small number of the reticulated layers, it is easy, by a proper adjustment of the focus of the microscope, to bring either one of them into distinct view. In whatever direction we slice the shell of the Echinus, we always meet with a sort of reticulated structure; for if our section be parallel to the surface of the plates, it brings into view one or more of the perforated laminæ just described; whilst, if it be perpendicular to the surface, it passes vertically through a series of these laminæ, and in the direction of the pillars that connect them, which thus constitute an areolar structure of a tolerably regular form. The testa is thus of an extremely porous character, the areolæ having the freest communication with each other. Even in the living state, however, the areolæ appear to be empty, the ingress of the fluid with which the surface of the shell is in contact being prevented by the delicate membrane that covers it. At the same time, it possesses a remarkable degree of strength, in proportion to the amount of solid matter employed in its construction; for every part at the same time supports, and is supported, by the surrounding fabric.

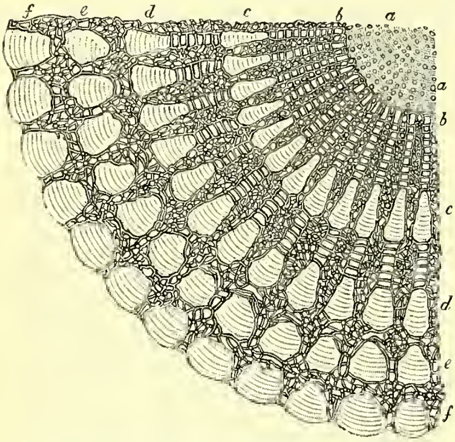
The skeleton of the Echinodermata contains very little organic matter. When it is submitted to the action of dilute acid, so that the calcareous matter is removed, the residuum is very small in amount; indeed, unless the acid be so weak as *only just* to dissolve the carbonate of lime, the organic matter also will be dissolved, and no animal basis will be apparent. When, however, it is obtained in a state fit for examination, it is found to possess the reticular structure of the calcareous shell; the meshes or areolæ being bounded by a substance in which a fibrous appearance, intermingled with granules, may be discerned under a sufficiently high magnifying power, as was first pointed out by Professor Valentin. This tissue bears a close resemblance to the *areolar* tissue of higher animals; and the shell may probably be considered as formed, not by the consolidation of the cells of the epidermis, as in the Mollusca, but by the calcification of the fibro-areolar tissue of the true skin. This calcification of areolar or simply fibrous tissue, by the deposit of mineral substance, not in the meshes of areolæ, but in intimate union with the organic basis, is a condition of much interest to the physiologist; for it presents us with an example, even in this low grade of the animal kingdom, of a process which seems to have an important share in the formation and growth of bone, viz. the progressive calcification of the fibrous tissue of the periosteum.*

Not only the entire shell, but the framework by which the teeth of the Echinus are enclosed and supported, is composed of a calcareous reticulation similar to that now described; nor is it confined to these solid structures. It has been pointed out by Professor Valentin, that the buccal membrane contains isolated patches of extreme delicacy; and the same eminent observer has detected a most beautiful example of this

* See Dr. Sharpey's Introduction to the Fifth Edition of Dr. Quain's Anatomy, p. 148, *et seq.*

structure in the calcareous rosette, with which, as long since observed by Monro, the sucker at the extremity of each ambulacral tube is furnished. But it is in the spines with which the shell is beset, that the most remarkable displays of it are to be met with ; for it is there disposed in connection with solid ribs or pillars, which increase the strength of these organs, in such a manner as to constitute a most regular and elaborate pattern, which appears to differ in every distinct species. When we make a thin transverse section of almost any spine belonging to the genus Echinus, we are at once made aware of the existence of a number of concentric layers, arranged in a manner that strongly reminds us of the layers of wood in the stem of an exogenous tree. The number of these layers is extremely variable ; depending, not merely upon the age of the spine, but upon the part of its length from which the section is taken. The centre of the spine (*fig.* 424. *a.*) is filled up

Fig. 424.



Transverse section of spine of Echinus : *a*, medullary centre ; *b b*, first layer of solid pillars ; *c c*, *d d*, *e e*, *f f*, successive rings of growth. *Magnified* 45 *diameters.*

with the same kind of calcareous net-work as that of which the shell is composed ; and this is sometimes so delicate, as to appear as if made up by the interlacement of mere threads. This medullary centre is bounded by a row, more or less circular according to the form of the spine (which is sometimes angular), of open spots (*b*, *b*, *b*), in which it is deficient : these, on a cursory inspection, might be supposed, from their transparency, to be void spaces ; but a closer inspection makes it evident that they are the sections of a circular row of solid ribs or pillars, which form the exterior of every layer. Their solidity becomes very obvious when we either examine a section of a spine whose substance is pervaded (as frequently happens) with a deep colour, or when we look at a thin section of any spine by polarised light. Around the first circle of these solid pillars, we find another layer of the fibro-calcareous net-work, which again is bounded by another circle of solid pillars, whose transverse sections are seen at *c*, *c*, *c*. The same arrangement may be repeated many times, (*d d*, *e e*). On looking at the outer border of the section, we observe that the rounded sides of these pillars (*f*, *f*) form a series of projections with hollows between them ; and these exactly correspond with the projecting ribs and furrows which we may notice running along the natural surface of the spine when we examine this with a magnifying glass, or even (in some instances) with the naked eye.

Although there is nothing like interstitial growth in the shell or spines of the Echinus, yet both are progressively enlarged by the addition of new matter. The polygonal plates of which the shell is composed are separated from each other by a membrane that passes into every suture ; and the margins of each plate appear to receive periodical additions, by calcareous deposit in the substance of this membrane. In this manner the globular form of the entire shell is preserved, whilst it undergoes progressive enlargement ; new plates being added, as they may be required, round the anal orifice of the shell (Agassiz). There can be little doubt that the spines are, in like manner, periodically augmented in diameter by successive formations or acts of growth, which take place in the investing membrane ; and a longitudinal section of the spine makes it evident that these additions not only surround the preceding deposits from the base upwards, but pass considerably beyond them, thus adding to the length of the spine. The consequence is, that a transverse section taken near the base of the spine will exhibit *all* the layers of which it is made up, each layer being narrow, and the central medulla small. A section taken at about the middle of the length may very probably not cut across the original spine nor the older layers, which do not reach so far ; and a section taken across the spine near its apex will only traverse the one or two layers last formed. Nevertheless, in many species, the spine is larger at that part than near its base ; but the large size is due to the great expansion of the medullary centre, which is composed of a very loose calcareous reticulation.

The structure of the shell of the *Echinus* is repeated in that of the three genera which may be regarded as the types of the principal subdivisions of the order Echinida, — namely, *Cidaris*, *Clypeaster*, and *Spatangus :* there can be no reasonable doubt, therefore, that it is universal throughout the group. The spines, however, of *Cidaris*, present a marked variation from the plan of structure exhibited in Echinus ; for they are usually nearly cylindrical in form, destitute of concentric layers, and composed of a calcareous reticulation enveloped in a cylinder of a solid, apparently homogeneous substance, chiefly calcareous,

which rises up in ridges upon the exterior. Hence it would appear that, like endogenous trees, whatever additions these spines may receive in length, they can receive little or none in diameter. The slender, almost filamentary species of the *Spatangaceæ*, and the innumerable minute hair-like processes attached to the shell of the *Clypeasteridæ*, are composed of a like regular reticulated tissue; many of these are extremely beautiful objects when examined with the microscope without any preparation. It is interesting also to remark, that the same structure presents itself in the *Pedicellariæ*, which are found upon the surface of many Echinida, and which have been so great a source of perplexity to naturalists. The complete conformity which exists between the structure of their skeleton, and that of the animal to which they are attached, would seem to remove all reasonable doubt that they are truly appendages to it; as their actions also would indicate.

The same structure presents itself in the calcareous plates which form the less perfect skeletons of the *Asteriadæ*, and also in their spines, when these (as in the large *Goniaster equestris*) are furnished with a calcareous frame-work, and are not mere projections of the hard integument. It is also met with in the family *Ophiuridæ*, which forms, in some respects, the transition to the Crinoidal group; but the calcareous skeleton is here generally subordinate to the firm and almost horny integument. In the *Crinoidea*, on the other hand, the calcareous skeleton is highly developed, and its structure is extremely characteristic. This is well displayed in the recent *Pentacrinus Caput Medusæ*, the stem and branches of which are made up of a calcareous net-work, closely resembling that of the shell of the Echinus. There is exhibited, moreover, in a transverse section of the stem of *Pentacrinus*, as in the spines of Echinus, a certain regular *pattern*, which results from the varying dimensions of the areolæ in different parts. This pattern, formed by the extension of five pairs of *rays* (strongly reminding us of the medullary rays of plants) from the centre towards the circumference, is frequently well preserved in the fossilized stems of *Pentacrini*, and varies in different species sufficiently to serve as a distinctive character. In the round-stemmed *Encrinites*, a transverse section of the joints exhibits a simple concentric arrangement.

It only remains for us to notice the order *Holothuridæ*, in which, as is well known, the calcareous skeleton of the other Echinodermata is reduced to its most rudimentary condition; never forming a complete and connected framework, but only showing itself in detached pieces, the disposition of which is extremely variable. In the typical *Holothuria*, there are five solid calcareous plates around the mouth, in which the calcareous reticulation is very characteristically seen. Each of the tentacula, also, has a small calcareous disk at its extremity, which presents a sort of rude sketch of the beautiful structure of the rosette that supports the ambulacral suckers of the Echinus.

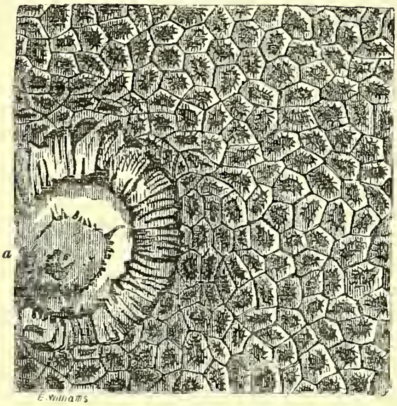
There can be no reasonable doubt that this peculiar arrangement is universal throughout the group, since it has been detected in characteristic examples of every one of its principal subdivisions. And, consequently, as no similar calcareous reticulation is found in the internal or external skeleton of any other animal, even the minutest fragment which distinctly presents this structure may be referred with certainty to an Echinoderm. And this structure is perfectly preserved, even after the substance has been infiltrated with calcareous matter in the act of fossilization, and has become so completely mineralised, that the disposition to rhomboidal fracture makes it difficult to obtain a section in any other direction than that of the plane of cleavage. As already remarked, the elementary structure is essentially the same everywhere; so that it might not be possible to determine from a very minute fragment whether it formed part of the shell of an *Echinus*, *Cidaris*, or *Spatangus*,—a portion of the framework of an *Asterias*, *Ophiura*, or *Holothuria*, — or entered into the composition of the stem of an *Encrinite*. But where any regular *pattern* is displayed, this is frequently sufficient to distinguish the genus, or even the species, to which the fragment belonged. This is certainly the case in regard to the spines of *Cidarites* and the stems of *Pentacrinites*; and will probably be found no less true in other instances, when these beautiful structures shall have been more extensively investigated.

Crustacea. — The structure of the shell in Crustacea has been hitherto examined only in the Decapod order; and that of the common crab (*Platycarcinus pagurus*) alone has been subjected to a minute investigation. It is in the Decapod order that the shell attains its most perfect development, and contains the largest proportion of mineral matter: the special respiratory apparatus in this order being so elaborate as to render unnecessary any participation of the general tegumentary surface in the function of respiration. (See vol. i. p. 752.)

The shell of the Decapod Crustacea consists of three layers; — namely, 1. a horny epidermic membrane covering the exterior; 2. a cellular or pigmentary stratum; and 3. a calcareous or tubular substance. The horny epidermic membrane is easily detached from the subjacent layers, after the shell has been immersed for a time in dilute acid; it is thin but tenacious, presenting no trace of structure, though it may exhibit markings on the under surface, derived from its contact with the cellular layer beneath. The pigmentary stratum is very thin in the crab and lobster; but in some other Decapods it is much thicker. In *Scyllurus latus*, it is stated by M. Lavalle to be the thickest of the three layers of the shell; and in the cray-fish and many other species, according to the same observer, it seems made up of a considerable number of layers, its vertical section being traversed by several ex-

tremely fine lines, passing in a direction parallel to the surface of the shell and to each other. The number of these is usually from six to fifteen; but they sometimes amount to as many as thirty, or even sixty, their number not being in relation either to the thickness of the pigmentary layer, nor to the size of the species observed; but appearing to augment with age. The cellular layer is that in which the colouring matter of the shell is solely contained; but it does not always contain pigment, its structure being precisely the same on the white under-surface of the crab as on the reddest portion of its carapace. When examined with a low magnifying power, it presents an areolar aspect; but when a sufficiently thin section is viewed by transmitted light with a high magnifying power, the character of the net-work, and of the dark spaces it encloses, becomes at once apparent. It is

Fig. 425.

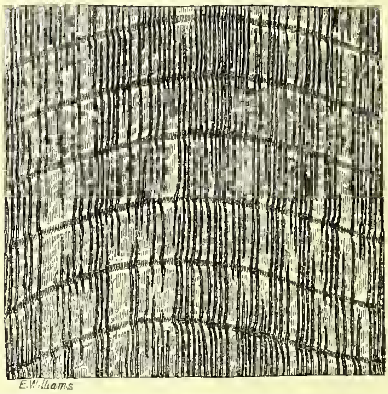


Cells of pigmentary layer of shell of Crab; a, papillary elevation of subjacent layer. *Magnified* 400 *diameters.*

then obvious that the nearly colourless polygonal reticulations are the thickened *walls* of cells, each of them being divided by a distinct line, which marks the junction of the contiguous boundaries; whilst the dark spaces or areolæ are the *cavities* of the cells, filled with colouring matter, or with some other semi-opaque substance. This cellular layer is not uniformly disposed over the entire surface of the crab-shell; for the calcareous layer beneath rises up through it in little papillary elevations (*fig.* 425. *a*), to the summit of which the epidermis adheres. It is from the deficiency of the pigmentary layer at these points, that the shell derives its minutely speckled appearance.

The internal layer is that which constitutes by far the thickest part of the shell of the crab, and which must be regarded as its fundamental or essential element, since (according to M. Lavalle) it is never wanting in the Decapod Crustacea, whilst other layers are sometimes deficient. It is in this internal layer, that the calcareous matter is chiefly deposited; but even after this has been removed, a very distinct animal basis is left, possessing considerable firmness, and closely resembling that which is left after the decalcification of dentine. When a thin section of it is made parallel to its surface, and subjected to a high magnifying power, it is seen to be composed of an apparently homogeneous substance, studded with minute points, each surrounded by a clear space, which correspond with those seen in a section of dentine cut at right angles to the course of its tubuli, and which would seem to possess the same essential character with them. A thin section of the shell taken in the opposite direction (*i. e.* from surface to surface) leaves no doubt, when examined with a sufficient magnifying power, of the nature of these markings; for they are then clearly seen to be the orifices of tubuli, which pass with great regularity from one surface of the shell to the other, lying nearly parallel to each other, and having their usually straight course interrupted at tolerably regular intervals by minute sinuosi-

Fig. 426.



Portion of transverse section from claw of Crab. Magnified 400 *diameters.*

ties resembling the "secondary curvatures" described by Prof. Owen in the dentinal tubuli. These sinuosities correspond with bands which are seen to traverse the section, running parallel to the surfaces of the shell; and they appear, like those of dentine, to indicate the successive stages of calcification of the animal basis. This structure is particularly well seen in the black extremities of the claws of the common crab, in which the intertubular substance is quite transparent in a thin section, and of which the hardness and density are as great as in many varieties of dentine; and as the tubuli are seen, in a transverse section of the claw, to *radiate* from the central cavity towards the surface, the resemblance to a section of a tooth is altogether so close, as quite to deceive an observer unacquainted with the substance he is examining. The same structure exists, however, in the remainder of the shell; but from some difference in its molecular constitution, the intertubular substance has a less dense and tenacious character, and has an opaque chalky aspect, which renders even a very thin

section of it impermeable to light, unless it be saturated with Canada balsam, which then very commonly enters the tubuli, and prevents them from being readily distinguishable. The purpose of the extraordinary density possessed by the extremities of the claws, is evidently to adapt them to the various mechanical uses to which the animal applies them: and it is interesting to see that this is attained without any variation in the organic structure of the part, but merely by a more intimate union, as it would seem, of the solidifying mineral matter with the organic basis. It does not seem improbable that the phosphate of lime which is known to be present with the carbonate in the shells of Crustacea, may exist in larger proportion towards the extremities of the claws than in other parts of the shell; a question well worthy of chemical investigation.

The periodical *exuviation* of the shell does not appear to be common to all Crustacea; for, according to Mr. Couch*, it does not take place in many of the sessile-eyed tribes, whose cases are as dense as those of the pedunculate orders. It is much to be desired that careful observations should be made on the formation of the new shell in the Crab; since these would probably throw light on much that still remains obscure in the development of dentine.

[The author of the forgoing article is desirous that it should be understood that all the statements contained in it, except such as are expressly made on the authority of others, are the result of his own observations; the general facts regarding the organic structure of the shells of Mollusca, Echinodermata, and Crustacea, having been determined by him in the year 1842, and embodied in a paper read before the Royal Society, Dec. 22 of that year, of which the first of the memoirs cited is an abridgment; and the subject having been subsequently worked out by him in detail, with the aid and encouragement of the British Association, to the reports of which he would refer the reader who may desire additional information as to the results of his researches.]

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(*W. B. Carpenter.*)

SHOULDER JOINT (Normal Anatomy of). †

The scapular and the axillary regions are each limited externally by the region of the shoulder-joint; the latter also unites the two former regions to each other.

The region of the shoulder joint (*le moignon de l'épaule*) exhibits a rounded projection, due to the angle formed by the union of the arm with the shoulder; and to the surgical anatomist it possesses extreme interest, because its skeleton is formed by the shoulder-joint.

Some difficulty arises in assigning to this surgical region precise limits. *Anteriorly*, it is separated from the pectoral region, by the narrow space between the deltoid and the great pectoral muscles (the *coraco-deltoid groove*, Velpeau); *above*, it is limited by the convex projection of the acromion process, and by the outer end of the clavicle; *posteriorly*, it is confounded with the scapular region; whilst *inferiorly*, it extends as far as the insertion of the *folds of the axilla*.

The elements of which this region is composed, are the following: under the superficial coverings lie the deltoid muscle (the greater portion of which belongs exclusively to this space), and in it and beneath it, the branches of the circumflex arteries, and of the great circumflex nerve; still deeper are situated the exterior of the capsule of the shoulder-joint, the neck and tuberosities of the humerus, the acromion and coracoid processes, with the attachment to them of numerous muscles and ligaments.

In this article it is proposed to notice, *first*, the structures in the scapulo-humeral region which are superficial to the joint; and, *secondly*, to describe the anatomical characters of the shoulder joint itself.

In removing the integuments and subcutaneous layer of areolar tissue which covers the deltoid muscle, the anatomist brings into view numerous small branches of nerves from the cervical plexus (*supra-acromial twigs*), some of the fibres of origin of the platysma myoides, and some small venous branches which, after anastomosing freely with one another, terminate in the cephalic or axillary trunks.

By the removal of its investing fascia, the *deltoid muscle* is next exposed: in its origin it corresponds accurately to the insertion of the trapezius; hence these two muscles are direct antagonists of each other. The fibres of the deltoid muscle *arise* from the anterior edge of the outer third of the clavicle and of the acromion process, and from the lower margin of the spine of the scapula: from this extensive line of origin, the fibres in descending converge to the humerus, and are inserted on the outer aspect of that bone into a rough surface called the *deltoid impression*. The insertion of the muscle is outside the limits of the scapulo-humeral region, and belongs to that of the arm, whilst its posterior portion is contained in the scapular region; so that the anterior, upper, and central portions of the deltoid alone belong to the region under consideration. Immediately beneath the clavicle, the anterior edge of the deltoid is separated from the pectoralis major by a triangular interval, of which *the base*, placed superiorly,

* Report of Cornwall Polytechnic Society, 1843.

† This article includes the surgical anatomy of the scapulo-humeral articulation.

is formed by the bone, whilst the edges are constituted by the adjacent muscles ; inferiorly, the interstice becoming smaller degenerates into a groove, which continues to separate the muscles from each other, until at length the clavicular fibres of the great pectoral unite with the deltoid, and are inserted conjointly with it into the humerus. In this muscular interstice the cephalic vein is lodged, which, ascending to the triangular space below the clavicle, there dips into the axilla, and joins the axillary vein. The descending branch of the thoracica acromialis (*arteria thoracica humeraria*) descends in the same groove, twisting in a spiral manner around the cephalic vein. More deeply still the *ligamentum bicorne*, enclosing between its layers the subclavius muscle, may be seen. The axillary vein and artery, brachial plexus of nerves, and inferior to these and crossing before them, the lesser pectoral muscle, may also be made apparent in this space; but to bring these latter parts into view, the anatomist must first freely separate the muscles from each other.

It has been proposed by Hodgson, in order to place a ligature around the axillary artery in the first stage, to cut between the pectoral and deltoid muscles, and then to separate the clavicular attachment of the great pectoral to an extent sufficient for insulating and tying the artery.

As in other radiated muscles, the tendinous structure of the deltoid is chiefly placed in its interior ; as many as three or four laminæ attached to the bone above, penetrate into the substance of the muscle, and multiply the points of origin of its fleshy fibres. The fasciculi, of which the deltoid muscle is composed, like those of the glutæus maximus, which is its analogue in the lower extremity, are remarkably coarse and large.

When the deltoid is cut across and reflected, the following parts are found in relation with its deep surface ; anteriorly is seen the coracoid process and the insertions of the pectoralis minor, of the coraco-brachialis, and of the short head of the biceps into its inner edge, and of the ligamentum bicorne (coraco-clavicular ligament) into its summit ; external to the coracoid process is a triangular space, the sides constituted by the opposed edges of the coracoid and acromion processes, the apex placed superiorly at the clavicle, the base inferiorly formed by the convex prominence of the head of the humerus ; this space, filled by the coraco-acromial or triangular ligament, should be familiar to the surgeon, as the point of the knife must be here introduced when disarticulation at the shoulder-joint is being performed after the method of MM. Champesme and Lisfranc. Immediately beneath the coraco-acromial triangle the capsular ligament is situated, and a large bursa (subdeltoid) which intervenes between it and the deep surface of the deltoid muscle ; still lower down, the insertions of the capsular muscles into the tuberosities of the humerus, also the neck of the humerus, and the bicipital groove, present themselves. The bicipital groove looks directly forwards and lodges the long tendon of the biceps ; into its anterior edge the tendon of the pectoralis major is inserted, whilst those of the latissimus dorsi and teres major take attachment to the very bottom of the groove, passing a little below the level of the former. The anastomosis of the circumflex arteries, and the circumflex nerve in a great part of its course, constitute also remarkable relations to the deltoid, separating it from the neck of the humerus ; and under the posterior division of the muscle are placed the infra-spinatus, teretes and latissimus dorsi muscles, with the triangular and quadrilateral spaces which they circumscribe. (*Vide* SCAPULAR REGION.)

The anterior and the posterior fibres of the deltoid may act independently of each other, and draw the arm forwards and upwards, or backwards and upwards, respectively. The central portion of the muscle is the principal abductor of the upper extremity ; although its insertion is at a considerable distance from the fulcrum, and the power arm of the lever on which it acts is therefore of considerable length, yet the efficient power of the muscle, relatively to its size, is feeble, owing to the fibres whilst in action being invariably parallel to the lever which they are raising. In this action the deltoid is assisted by the supraspinatus muscle.

SCAPULO-HUMERAL ARTICULATION. — The scapulo-humeral articulation is formed by the contact of the head of the humerus with the glenoid cavity of the scapula. This, the principal articulation of the upper extremity, is placed at the superior and external portion of the trunk, behind the line of the axis of the hip-joint ; an arrangement which is productive of this advantage, that the most important motions of the upper extremity (those in the direction forwards) have a more extensive range than if the articulation had been located nearer to the anterior aspect of the thorax.

The arrangement of the articular surfaces and of the ligamentous structures belonging to the shoulder joint, accords with the general plan on which the bones and articulations of the upper extremity are constructed ; " the disposition and structure of the bones of the upper extremity afford a marked contrast to those of the lower ; the latter are organs of support, and therefore are solid, firm, strong, and withal elastic. The former are destined to perform extended motions, as well as minute and nicely adjusted ones, and therefore, while they possess all the requisite strength, they are light, present little expanse of surface, and are articulated by numerous very moveable articulations." (*Todd and Bowman's Physiological Anatomy*, vol. i. p. 147.)

The varied uses fulfilled by the upper extremity, added to its remarkable mobility, especially predispose the shoulder joint to accidents; but as we proceed we shall take

occasion to point out the abundant provisions which exist to counteract this tendency.

As regards its motions, and the anatomical dispositions of its connecting media, the shoulder joint belongs to the class of "Enarthrodial Articulations;" but, if its bony constituents alone be considered, it seems more nearly allied to the "Arthrodia." This is owing to the imperfect development of the glenoid cavity which is opposed to the head of the humerus.

The shoulder joint is constructed after the same plan in all vertebrate animals whose anterior extremities are developed.

In this article the several components of the scapulo-humeral articulation shall be described in the following order:—

1. THE BONES. 2. THE STRUCTURES WHICH FACILITATE THEIR MOTIONS. *a. Articular Fibro-Cartilage. b. Articular Cartilage. c. Synovial Membrane.* 3. THE CONNECTING MEDIA. *a. Passive connecting Media — the Ligaments. b. Active connecting Media — the Muscles;* in connection with the detail of the *Mechanical Functions* of the joint.

1. *Bones.*—We shall speak of these briefly, as they have been already described in the article *Extremity.*

The bones which enter into the formation of the shoulder joint are, the head of the humerus and the glenoid cavity of the scapula. These opposed surfaces are of very disproportionate size, the shallow cavity of the scapula not exceeding in dimensions one-third of the head of the humerus.

The *glenoid cavity* is placed at the anterior superior angle of the scapula, below and between the acromion and coracoid processes; a slight constriction, the *neck of the scapula*, separates it, together with the coracoid process, from the body of the scapula; *superiorly*, the neck of the scapula traverses the notch in the superior costa of the bone, behind the base of the coracoid process; *inferiorly*, it terminates close to the lower extremity of the articular surface. The *aspect* of the glenoid cavity in the quiescent state of the scapula, is upwards, forwards, and outwards; it presents an ovoid outline, the larger end below, and the smaller above. A vertical line falling upon the axillary margin of the scapula divides this articular cavity into two unequal portions, of which the inner is the larger. This arrangement in some degree diminishes the tendency to displacement inwards of the head of the humerus, to which, for other reasons, the joint is strongly disposed.

An "arrest of development" may cause a deficiency of either the outer or the inner lip of the glenoid cavity, resulting in a congenital dislocation of the head of the humerus, inwards or outwards, according to the portion of the cavity which is deficient. These constitute the "sub-acromial" and "sub-coracoid" dislocations described by Dr. R. Smith.*

Boyer supposes that a deficient development of the outer lip of the glenoid cavity must pre-exist, in order to permit the dislocation backwards on the dorsum of the scapula to occur.*

A little external to its apex, a slight notch in the margin of the glenoid cavity marks the place of attachment of the long tendon of the biceps; whilst on its upper and inner side a shallow groove points out the passage of the tendon of the subscapularis muscle.

The *head of the humerus* presents a convex hemispherical surface, the aspect of which is upwards, backwards, and inwards. An irregular wavy line separates the head from the anatomical neck of the bone, the latter intervening between the head and the tuberosities. The line which marks the union of the upper epiphysis with the shaft of the humerus has been long incorrectly described, as though it were identical with the anatomical neck. The upper epiphysis comprises not only the head of the bone, *but also the tuberosities;* for though, doubtless, the line of junction between the upper epiphysis and the shaft corresponds *internally* to the anatomical neck immediately beneath the cartilage of incrustation, yet from this its direction is chiefly outwards, so that *externally* it passes below the greater and the lesser tuberosities, traversing the bicipital groove which is included between them.

This anatomical fact, and the practical inferences derivable from it, have been clearly pointed out by Dr. R. Smith.†

2. *Structures which facilitate motion in the joint.*—*a.* The border of the glenoid cavity has attached to it a fibro-cartilaginous rim (*glenoid ligament*) by which the depth of the cavity is somewhat increased. This structure is thickest at its attachment to the bone; its free edge is very thin; a section of it made at right angles to the bone gives it a triangular outline. Both its surfaces are lined by synovial membrane, which consequently separates it externally from the capsular ligament; superiorly, many fibres of the biceps tendon become continuous with the fibrous portion of the so-called "glenoid ligament," and after prolonged maceration the tendon will separate from the bone along with this structure, but to describe the glenoid ligament as formed by the splitting of the tendon of the biceps, would be erroneous. The glenoid ligament is subservient to the following purposes: it deepens the shallow glenoid cavity, and so lessens the liability to dislocation; it prevents the bony surfaces of the neck of the humerus, and the edge of the glenoid cavity, from being unduly pressed against each other in the extensive motions of the joint; and it gives a more extended, and therefore a more secure attachment to the tendon of the biceps.

b. The articular surfaces are invested with *cartilage of incrustation*, which, in accordance with a very general rule, is much thicker at the centre of the convex head of the humerus

* Dublin Journal of Medical Science, vol. xv., 1839.

* Traité des Maladies Chirurgicales, tom. iv. p. 176.

† Essay on Fractures, &c., p. 203. Dublin, 1848.

than at the circumference; whilst the reverse is true of the glenoid cavity, the cartilage being there of greater depth at the circumference than at the centre.

The anatomical disposition of (*c.*) the *synovial membrane*, can be more conveniently studied after the ligaments have been examined.

3. *Connecting Media. Capsular ligament.*—This is a fibrous expansion which in its general character resembles the capsular ligament of other articulations. The capsule of the shoulder joint is remarkable for its capaciousness, and consequent laxity—an arrangement which permits the great freedom of motion enjoyed by this articulation. It embraces the margin of the glenoid cavity above, and is prolonged upon the tuberosities of the humerus inferiorly; hence it may be described as a sac having two apertures, of which the lower is by far the larger. Viewed externally, its form is that of a hollow cone, the base of which is placed inferiorly. The fibres which compose the capsule are extremely irregular in direction, nor are they of uniform strength or thickness. The capsule is very thin, posteriorly and also internally; in the latter direction, it is almost aways deficient, so that the cavity of the joint is continuous with that of the synovial bursa, beneath the tendon of the subscapularis muscle; more rarely, an opening in the capsule establishes a communication between the serous cavity of the shoulder joint and a bursa under the infra-spinatus muscle. The capsule possesses considerable strength anteriorly and above, being there reinforced by a thick bundle of fibres, sometimes described as a distinct ligament, under the name of *coraco-humeral*, or *accessory*. These fibres are attached superiorly to the under surface of the coracoid process, they thence follow an oblique course downwards and outwards, become incorporated with the proper fibres of the capsule, and are traceable inferiorly to the great tuberosity of the humerus, crossing anterior to its bicipital groove. Inferiorly, or towards the region of the axilla, the capsule possesses much intrinsic strength, though here totally devoid of any muscular or tendinous coverings. When the arm is much abducted, the head of the humerus presses strongly against this part of the ligament, which sometimes gives way, and the head of the bone escaping from the glenoid cavity, between the subscapular muscle, and the long head of the triceps, dislocation into the axilla is produced. In this accident, the head of the humerus generally detaches the subscapular muscle from the bone, and lies between that muscle and the subscapular fossa. The anatomist will not fail to observe that the subscapular nerve, as it runs from the brachial plexus outwards, to wind round the neck of the humerus, is closely related to this portion of the capsule which may be seen from the axilla, between the triceps and subscapularis muscles; and can, therefore, easily understand why the nerve in question should be sometimes torn or compressed, when the head of the humerus has been dislocated downwards and inwards; this complication of the axillary dislocation gives rise to paralysis of the deltoid muscle, partial or complete, temporary or permanent, according to the degree of injury which the nerve may have sustained.

The exterior of the capsular ligament is in close relation *superiorly* with the supra-spinatus, and *posteriorly* with the infra-spinatus and teres minor muscles; *inferiorly*, it is connected with the scapular origin (long head) of the triceps; whilst *anteriorly*, it is covered and partly replaced by the subscapularis. With the intervention of the capsular muscles, it is also related on its external, anterior, and posterior aspects to the deltoid muscle, and above to the coraco-acromial triangle. A large bursa is situated beneath the deltoid, and separates this muscle from the exterior of the capsule; it also gives an extensive investment to the tendons of the capsular muscles, and is evidently designed to favour the very free motions which those parts enjoy.

The long tendon of the biceps, placed exactly upon the anterior aspect of the bone, escapes from beneath the lower edge of the capsule, which here arches across the bicipital groove, and converts it into a canal; the capsule is not therefore perforated by the tendon of the biceps, as is stated by many anatomists. A portion of the synovial membrane descends with the tendon below the edge of the capsule, is again reflected on the groove, and so re-ascends into the joint, having formed a small "cul-de-sac," without the articulation.

From these relations with the surrounding muscles, the capsule derives much of its strength: the tendons of the four capsular muscles are inseparably united to the fibres of the ligament, which are prolonged inferiorly, as far as the lowest portion of the humeral tuberosities; posteriorly, it derives some fibres from the triceps; and from the upper edge of the tendon of the great pectoral muscle, (at its insertion into the anterior lip of the bicipital groove,) a fibrous fasciculus ascends, and likewise becomes identified with the capsule; this prolongation has been described, under the name of "suspensory frænum," by Winslow.

It must be obvious from this description, that the capsular ligament alone cannot maintain the bones of the shoulder joint in opposition: from its great laxity, it permits a considerable separation of the osseous surfaces, and they are maintained in contact with each other mainly by the tonic contraction of the surrounding muscles (which are placed in the most favourable position to accomplish this important object). Accordingly, in paralysis of the upper extremity, the limb becoming elongated, one or two fingers can be pressed into the joint towards the glenoid cavity, now abandoned by the head of the humerus; and, owing probably to a somewhat similar condition of parts, spontaneous dislocation of the humerus has been known to occur in the debilitated state of the sys-

tem consequent on the administration of mercury. Neither must the influence of atmospheric pressure be forgotten, which, exerting as it does a force of nearly fifteen pounds on the square inch, must powerfully contribute to preserve the contact of the articular surfaces.

Within the capsular ligament, and at the upper and outer part of the joint, two structures are found, which may, with propriety, be described as inter-articular ligaments; these are the tendon of the long head of the biceps, and the *gleno-humeral*, or *Flood's ligament*.

The *long tendon of the biceps* has been described already, as attached to the apex of the glenoid cavity, and to the fibrous portion of its circumferential fibro-cartilage. Surrounded by synovial membrane, it passes downwards and outwards, forming an arch over the head of the humerus, it then descends in the bicipital groove, where it is retained *in situ* by the fibres of the capsular, and of the accessory (*coraco-humeral*) ligaments.

Cruveilhier mentions that in two cases he found this tendon united by a strong adhesion to its groove, " thus justifying the name of ' inter-articular ligament :' the tendon for the long head of the biceps took its origin from the same groove." This condition, Cruveilhier supposes to have been the result of injury; but as the appearance in question has been seen by the writer, as the result of chronic rheumatism, affecting the scapulo-humeral articulation, he is compelled, although reluctantly, to dissent from such high authority, and to express his opinion that this change originated in rheumatism, not in accident; his opinion is farther borne out by the state of the inter-articular portion of the tendon in Cruveilhier's cases, for it is stated, that " the bicipital groove was depressed, and the inter-articular ligament flattened, and, as it were, lacerated."

The inter-articular portion of the tendon of the biceps, by itself, could scarcely protect the head of the humerus from displacement upwards, a use very commonly assigned to it, as the smooth convex head of the bone would readily slip from beneath it; but in the interior of the joint, a second band, the " gleno-humeral ligament," described by the late Dr. V. Flood, is thrown across the head of the humerus, and may contribute to oppose this luxation; we quote the following description of this ligament from Dr. Flood: — " It may be easily exposed," he says, " by cutting through the inferior part of the capsule transversely, and throwing back the arm over the head, you thus expose the interior of the upper part of the capsule, also the biceps tendon. Parallel to the inner edge of the latter, this ligament may be felt and exposed by a little dissection. The tendon of the subscapularis in passing to its insertion, rests in a notch in the superior and internal part of the edge of the cavity; from the edges of this notch, the ligament arises broad and flat, then proceeds along the internal edge of the biceps tendon, and becoming smaller and rounder, is inserted into a distinct pit in the anatomical neck of the humerus, at the inner edge of the bicipital groove. In its triangular form, its origin at a notch in the articular fossa, and its insertion into a pit, it strongly resembles the ' ligamentum teres ' of the hip-joint." *

In nearly all the specimens examined by the writer, the upper half of this ligament had both its surfaces invested by the synovial membrane. This enables the dissector readily to distinguish it from the capsule; but inferiorly, its fibres are generally identified with this structure, and therefore it loses the appearance of a distinct ligament, before arriving at the humerus.

With the mode of its origin, and its intra-capsular position, all resemblance between this structure and the " ligamentum teres " in the hip-joint, ceases; the latter has little of the structure, and fulfils none of the uses of a ligament. Not so the " gleno-humeral ligament :" its structure is distinctly fibrous, it possesses great powers of resistance, and it is an auxiliary to the tendon of the biceps, so that both together are enabled to restrain the undue ascent of the humerus; an object which it seems probable neither of them could accomplish, unaided by the other.

Synovial membrane. — In its arrangement and general characters, the synovial membrane of the shoulder joint differs in no way from that of other articulations. As the fibrous capsule is lax, so the serous membrane, which lines it, presents a cavity of large size. Having covered the articular cartilage of the head, it passes downwards on the neck and tuberosities of the humerus, as far as the lower attachment of the capsule, to the inner surface of which it is thence reflected: having lined the capsule, the synovial membrane arrives at the glenoid cavity, the articular surface of which it similarly invests; it forms sheaths for the inter-articular ligaments, for the long tendon of the biceps, and for the gleno-humeral ligament: that for the former, as has been already described, extends along the bicipital groove, even beyond the limits of the capsule. Internally, where the capsule is deficient, the synovial membrane covers the corresponding portion of the tendon of the subscapularis, and here a communication is established between the cavity of the serous membrane of the articulation and that of the bursa mucosa, which is found beneath that muscle. A similar communication sometimes exists posteriorly between the cavity of the joint and the bursa, which is subjacent to the infra-spinatus muscle. A few fatty folds are generally found attached to the reflections of the membrane.

In connection with the scapulo-humeral articulation, the remarkable vaulted arch placed above it remains to be described. This is constituted by the acromion and coracoid processes, and the intermediate ligament. It may be regarded as supplemental to the

* Lancet, 1829-30, p. 672.

shoulder joint, and as being intended to compensate for the incomplete reception of the head of the humerus by the glenoid cavity. The centre of this arch is formed by the coraco-acromial or triangular ligament, of which the apex is situated at the acromion, and the base at the outer edge of the coracoid process. The ligament consists of two bundles, separated by a cellular interval, and placed more anteriorly the one than the other. The acromion and coracoid processes constitute respectively the extremities and the points of support to the arch, whilst its under surface is accurately adapted to the convexity of the head of the humerus, the tendon of the supraspinatus muscle intervening. The existence of the large bursa (elsewhere noticed) between this tendon and the coraco-acromial ligament, abundantly proves that considerable motion takes place between them : the upper surface of the ligament is concealed by the deltoid muscle.

In this arrangement may be recognised a provision for protecting the shoulder-joint against violence from above (*Voute protectatrice*, Blaudin), and the humerus against displacement from below, either directly upwards or with an inclination backwards or forwards. And for such a provision there is the greater necessity, as the upper extremity is constantly exposed to forces which act upon it from below.

Mechanical functions. — In common with other enarthrodial articulations, the shoulder joint enjoys the following varieties of motion : 1. Flexion ; 2. extension ; 3. adduction ; 4. abduction ; 5. circumduction ; and 6. rotation.

1. Of the opposed motions of *flexion* and extension, the former possesses the greater latitude. When carried to its utmost extent, the humerus appears to move through the arc of half a circle of which the centre is at the joint ; for the arm from being parallel to the trunk in the direction downwards, may by this motion be raised vertically upwards.

2. *Extension*, on the other hand, is much more limited, being restrained by the great strength of the anterior portion of the capsule, by the inter-articular ligaments, and by the contact of the head of the humerus with the coracoid process, which are all calculated to check the advance of the head of the humerus, the necessary result of extension.

Flexion and extension, although apparently performed in the scapulo-humeral articulation solely, are really distributed over a much more extended sphere, being shared by the scapula, and by the articulations of the clavicle with the acromion and with the sternum.

When extreme flexion or extension takes place, the scapula undergoes a motion of rotation upon its axis (an imaginary line passing through the centre of the bone) ; and the result is, that when the humerus is flexed the superior angle of the scapula moves backwards, and its inferior angle forwards ; whereas, in extension of the arm, a change of position the reverse of this is produced in the scapula. This rotation of the scapula is favoured by the looseness of the ligamentous connections of the acromio-clavicular articulation, whilst it is restrained within bounds by the coraco-clavicular ligaments (conoid and trapezoid). The trapezoid limits the advance of the upper angle of the scapula ; the conoid checks the rotation which would carry it in the opposite direction.

The muscles which chiefly effect the rotation of the scapula are, the trapezius, latissimus dorsi, levator anguli scapulæ, rhomboidei scapulæ, serratus magnus anticus, and the pectoralis minor. Of these the trapezius and serratus magnus rotate the scapula, so as to elevate its acromial end ; whilst the rhomboidei muscles and the pectoralis minor produce the contrary effect ; the latissimus dorsi can only act on the scapula when it takes an origin from its inferior angle. If it were possible for the levator anguli scapulæ to act independently of the other scapular muscles, it would depress the acromion ; but as this rarely, if ever occurs, its ordinary action is to assist those muscles which elevate the entire scapula, and, consequently, the shoulder joint.

3. The motions of *adduction* and abduction are remarkably contrasted : the former can hardly, with strict propriety, be said to exist, being prevented by the immediate contact of the arm with the side ; adduction, however, in an oblique direction forwards and inwards, is permitted. This motion is limited by the projection of the thorax : when the arm is placed in this position the head of the humerus is strongly pressed against the posterior portion of the capsule, and if force were to be applied to the distal extremity of the lever under these circumstances, dislocation backwards might be produced.

4. The motion of *abduction* is the most extensive of those enjoyed by the shoulder-joint ; it permits the separation of the arm from the side, until it becomes parallel to the trunk in a direction upwards ; flexion has been stated to be capable of the same range, but the latter owes much of its freedom to the mobility of the scapula, whereas in abduction the scapula moves but little, and nearly all the motion takes place in the scapulo-humeral articulation.

Abduction is limited by the contact of the neck of the humerus with the acromion, and by the resistance of the capsular ligament. When fully performed, the head of the humerus revolves in the glenoid cavity, and in its descent presses strongly against the inferior portion of the capsule ; if force be now applied to the upper extremity from above, the ligament may give way and dislocation be effected. More frequently this accident occurs when the arm is moderately abducted, and the mechanism by which, under such circumstances, it is effected, may be briefly explained. When a person falls on the inside of the elbow, while the arm is abducted, the upper extremity represents a lever of the third order, of which the fulcrum is at the point of contact of the elbow with the ground, and the power at the " folds of the axilla ;" the at-

tachment of these muscles at right angles to the lever, and at a considerable distance from the fulcrum, enables them to act at a great mechanical advantage, and their sudden contraction makes the upper end of the humerus to become the moveable extremity of the lever, and presses it against the capsule, which giving way between the triceps and the subscapularis muscles, allows the bone to escape into the subscapular fossa. The long diameter of the glenoid cavity being vertically placed is favourable to the motion of abduction, and in some degree lessens the liability to dislocation, to which the joint is so prone in this position, whilst on the other hand the comparative fixity of the scapula when the arm is being abducted, explains in some degree the frequency of dislocation of the humerus downwards.

5. *Circumduction* is compounded of the preceding motions, the flatness of the humeral tuberosities and the shallowness of the glenoid cavity rendering it very extensive in subservience to the variety of uses of the upper extremity. Circumduction is much more limited in the hip-joint, as there, the anatomical conditions which favour this motion in the shoulder are wanting, freedom of motion being sacrificed to security.

6. *Rotation* is imperfectly developed in the shoulder joint, but it exists in great perfection in the hip, as a necessary consequence of the great development of the neck of the femur.

(*Ben. Geo. M'Dowel.*)

SHOULDER JOINT, Abnormal Conditions of.—The alterations from the normal condition of the shoulder joint, which we have observed, may be classed under the three following heads: — First, those which are produced by disease; secondly, those caused by accidental injury; and, thirdly, those which are the result of congenital malformation.

Section I. — *Disease.* — The abnormal appearances observed in the joints in general, and in that of the shoulder in particular, resulting from *disease*, owe their origin to some local injury done to the joint, or to some specific irritation, such as gout, rheumatism, syphilis, struma, &c. Whether the disease first commences in the bone, the cartilage, or synovial membrane*, it soon involves all the structures of the articulation in the same morbid action, and with the local affection is usually associated some form of inflammation, either acute or chronic.

Acute arthritis of the shoulder.—The *symptoms* of acute inflammation of the shoulder joint will be found to be similar to those we have elsewhere in this work described as being present, when some of the other large articulations have been affected by it.† The patient will feel considerable pain in the shoulder joint, to the front of which he will point as the seat of his most acute suffering. This pain is aggravated by the slightest touch, or when any movement is communicated to the joint. The patient himself carefully preserves his arm immovably in one posture as he lies in bed, with his elbow abducted from his side, and his hand supported in the state of supination. Effusion of altered synovia, or purulent matter, rapidly takes place into the synovial sac of the articulation. There is much heat of the surface and tension of the skin. The pain which, as already mentioned, is felt on the front of the shoulder joint, soon extends down the arm to the inside of the elbow-joint, and the patient complains of spasmodic startings of the limb, and œdema of the whole extremity may supervene. The distention of the synovial sac of the articulation increases, and the surgeon can discover a fluctuation along the anterior or posterior border of the deltoid region, and he may find it expedient, with the view of relieving pain and tension, to make an incision into the joint, and thus give exit to a large quantity of purulent matter. Irritative, or it may be in some constitutions inflammatory, fever accompanies these symptoms, and the patient may be carried off even before the period when the purulent matter shall have made its way to the surface; or the acute inflammation may subside into chronic arthritis, and articular caries of the shoulder joint be established, to run its subsequent course as a chronic disease.

The acute form of the disease only differs from the chronic in the former being more intense in its attack, and in being accompanied with swelling of the joint — in being more rapid in its course, and more speedily producing complete disorganisation of the articular textures.

Anatomical characters of arthritis of the shoulder — Very few opportunities are offered to the anatomist of witnessing the appearances which the several tissues of the shoulder joint present when they have been the seat of acute inflammation; we may, however, safely infer, that the articular structure of this joint will be altered in a similar manner in consequence of an attack of acute arthritis, as the corresponding tissues in other joints have been already described.*

Chronic arthritis of the shoulder.— We meet, in practice, with two forms of chronic *arthritis* of the shoulder. The first of these occurs as an example of slow inflammation passing into either articular caries or anchylosis of the joint, and is analogous to the well-known scrofulous disease of the hip. The second furnishes us with a specimen of a chronic disease, which the writer has *elsewhere* in this work denominated *chronic rheumatic arthritis* †; a disease, the effects of which are to be traced in all the articulations, but its peculiarities are in no joint better exemplified than when the shoulder becomes the seat of it. We shall first treat of the abnormal appearances produced by the disease we call

* See Hip Joint, Vol. II. p. 790.

† See Vol. III. pp. 49—55; Hip Joint; also Vol. II. pp. 788—792.

* Vide Vol. III. p. 54.

† See Hand; Hip Joint; Elbow, &c. &c.

simple chronic arthritis of the shoulder; secondly, we shall describe those which belong to chronic rheumatic arthritis of the same articulation.

While the two chronic diseases of the hip, namely, the scrofulous affection and the chronic rheumatic arthritis of this joint, have of late years attracted much attention from the profession, it appears to the writer of this article that the corresponding diseases of the shoulder joint have been much overlooked. He hopes, therefore, he shall be excused if he deems it necessary to enter into more than ordinary details relative to the two chronic affections of the shoulder joint, which he will now endeavour faithfully to delineate.

Simple chronic arthritis of the shoulder may be the result of a sprain or contusion: the synovial and fibro-synovial structures are in this case principally affected. If, however, the inflammatory action be not arrested, the bones, as well as their cartilaginous incrustations, become ultimately engaged, and true articular caries is established. The disease sometimes begins in the shoulder joint, without the patient being able to assign any cause for it; and in this case it may have a constitutional origin, and be the result of struma, or acute rheumatism, which last having subsided in the other joints, has concentrated itself on this one articulation, assuming the form of an articular caries. We have known it also appear in a young female during the convalescence from a long-continued gastric fever.

Symptoms.—The first symptoms the patient suffers from, who is affected with simple chronic arthritis, or articular caries of the bones which enter into the formation of the shoulder joint, is a sensation of weight, weariness, and aching in the affected arm. These signs of the disease are at first not constantly present; they appear and then disappear, to return again in some days. Some stiffness in moving the affected arm is next complained of, to which is soon added pain, which the patient says is deeply seated in the joint, and which is augmented by using the articulation, or when the articular surfaces are pressed against each other. These symptoms are seldom so severe as to prevent the patient from following his ordinary occupations.

So far the disease may be said to be merely in its commencement; but very soon we observe it to pass into the second stage, when it may be discovered, on minute inquiry, that there is some sympathetic disturbance of the system — some heat of skin and slight acceleration of the pulse.

On examining the affected joint, we observe that the patient habitually carries it higher than the opposite shoulder, and the clavicle at the affected side is observed to pass, as it were, obliquely upwards and outwards, the adipose and cellular tissue, as well as all the muscles around the shoulder joint waste. The deltoid muscle, in a state of atrophy, appears stretched longitudinally, and the affected shoulder to have lost much of its normal roundness. The acromion process projects (see *fig.* 427.), and the arm of the affected side *appears*, and is usually found, on comparative measurement, to be *really* lengthened; the anterior fold of the axilla is deepened by the descent of the humerus from the glenoid cavity. The pain increases, and extends downwards from the shoulder to the inside of the elbow and wrist.

In *the third period* of the disease, the wasted condition of the muscles around the shoulder joint, as well as those of the whole upper extremity, becomes still more obvious, and now the arm, which was really longer than natural, becomes gradually shorter. It is quite possible that, after the limb has become shortened, any pain or uneasiness felt in the joint may subside, and a process of true anchylosis be established before suppuration takes place; but it much more frequently occurs, that about the time of the shortening of the limb, or subsequently, a chronic symptomatic abscess will make its appearance, and perhaps open spontaneously, in the axilla, or on some point along the outline of the deltoid, or inferior margin of the pectoral muscle; and then the disease may be said to be in the fourth stage.

This very serious chronic disease of the shoulder may be sometimes arrested in its early stage, and the patient recover the use of the joint; but, on the other hand, the disease frequently ends unfavourably by hectic fever, with its fatal consequences supervening. The more usual course for the disease to run will be found in general to be, that suppuration will take place, abscess after abscess will form, their purulent contents escaping and continuing to flow, greatly exhausting the strength and spirits of the patient; but under the influence of good air and judicious management, the discharge from the abscesses may cease, the constitution improve, and true bony anchylosis of the shoulder joint be established.

The history of the two following cases of simple chronic arthritis of the shoulder, at this moment (June, 1848) under treatment at the Richmond Hospital, will serve to illustrate some of the preceding observations as to the symptoms which patients usually labour under when affected by this chronic disease.

Case 1. *Chronic arthritis of the right shoulder joint of four years' duration. The disease in the* second *stage.* — Margaret Moore, æt. 27, servant, admitted March 8th, 1848, under the writer's care. She complained of stiffness and weakness of her right shoulder (*fig.* 427.), and of pain, which was much worse at night than during the day; she had also a constant uneasiness at the inner side of the right elbow, and her nights were restless, her sleep interrupted by spasmodic starting of the whole limb, and pain extending down to the wrist and back of the hand; she states that she has really more pain in the elbow and wrist than in her shoulder, and that these pains are increased when the arm is moved, or the articular surfaces *are pressed against each other.* When-

ever she moves her arm in the slightest degree the scapula follows the humerus, so

Fig. 427.

Case of M. Moore: Articular caries of the right shoulder joint; second stage of the disease.

that in the voluntary movements of the upper extremity really no motion takes place in the shoulder joint; but if we grasp the scapula, and thus firmly fix it, and at the same time move the humerus, a distinct crepitus is occasionally elicited, of which the patient herself also is conscious. When the arm is permitted for a moment to hang down by her side unsupported, she has great pain, and she feels the advantage of keeping it constantly in a sling, with her hand as high as her opposite collar bone. The muscles surrounding the right shoulder joint were observed to be in a wasted condition; this shoulder seemed higher up than the other, and the clavicle of this side to have a corresponding obliquity. The history she gives of the origin and progress of this disease is, that she has had a certain degree of pain and uneasiness in the articulation for the last four years, but that it never swelled much nor became inflamed, nor did it prevent her from following her occupation as housemaid, until three months ago, when she felt compelled to give up her situation. She referred the aggravation of her distress latterly to an injury the joint received from a severe fall she got down an entire flight of stairs. The latter circumstance in the history of her case made us more particular in our inquiries as to whether any fracture or dislocation could have occurred at the moment of this accident, and have been left unreduced. We were readily satisfied that there had been no fracture, as the affected arm was longer than the other.

The deltoid muscle was flattened and the acromion was seen presenting an angular projection as in an old luxation; yet the head of the humerus could be felt below the acromion; the anterior fold of the axilla was deeper than natural, but the elbow in this woman was placed habitually close to her side, and the long axis of the humerus could be traced by the eye to run nearly perpendicularly upwards towards the site of the glenoid cavity, and not more inwards towards the axilla, as in the case of luxation.

The atrophy we observed to affect the muscles in the vicinity of the diseased shoulder joint in this case, was not confined to the deltoid and capsular muscles; but the great pectoral was so much wasted that the ribs and intercostal interstices were seen conspicuously on the right side, while the corresponding spaces on the left side of the front of the thorax were sufficiently covered by muscle, &c. The right arm and forearm were more wasted than the left or unaffected limb, while the former extremity, measured from the acromion to the outer condyle of the humerus, shows an addition of length, or rather a descent of the humerus from the glenoid cavity, for the space of one inch. This woman has been subjected to the ordinary treatment for such cases; she feels the necessity of supporting her arm, and not allowing it out of the sling during the day, while she walks in the open air.

The foregoing case presents us, as we have said, with a good specimen of the *simple chronic arthritis*, or articular caries of the shoulder in the second stage of the disease. It is probable that a slow process of bony anchylosis will be ultimately established; and the woman after a time may lose all pain, regain her general health, and ultimately recover, but with the impediment which must ever attend an anchylosed shoulder joint. The course of the disease is not always so favourable; on the contrary, when the disease has arrived, as in the case of Moore just related, at the second stage, the pain is in some instances increased, the head of the humerus becomes wasted by caries as well as the surface of the glenoid cavity, when it will be found that the affected extremity, which was really longer than the other, shall have become shorter. This shortening, which marks the third stage of the disease, is frequently thought to be the result of complete dislocation; but this occurrence, the possibility of which we do not deny, we believe, however, to be exceedingly rare. The shortening may be the consequence of caries and absorption of the head of the humerus, as well as of the surface of the glenoid cavity. Under such circumstances the head of the bone may lean towards the axilla and subscapular fossa, or backwards towards the dorsum of the scapula; or it may be elevated, so as to reach the concavity of the coraco-acromial vault, and be maintained there by the tonic force of the elevator muscles; but we have not found it completely dislocated as a result of caries.

Case 2. Articular caries at the shoulder joint in the fourth stage of the disease. — Mary Ann Malloy, æt. 21, servant, admitted into the Richmond Hospital 25th July, 1847, under the care of Dr. Hutton. She has been now (June, 1848) eleven months

in hospital, and her left shoulder joint has in this period gone through all the stages of chronic arthritis; and a process of anchylosis, with shortening of the left upper extremity, appears to have been nearly completed. Her general health seems at this time but little affected: several depressions along the margins of the deltoid muscle, anteriorly and posteriorly, mark the situation of the numerous openings, most of which are now closed, through which purulent matter had escaped from the joint. The history which we collected of her case was, that about two months previously to her coming to the hospital she fell backwards on her left elbow, to which accident she ascribes her disease; that subsequently to this fall she felt pain in her left shoulder, but she cannot recollect that the joint swelled or became hot; on the contrary, the shoulder always seemed to her, from the first, to waste, and to be colder (as it is at this moment) than the other; except when the period of the formation of the abscesses arrived. She states that the movements of the joint, during the progress of the disease, were most painful, and that she had a sensation of something grating in the joint whenever the surgeon, in examining it, moved the arm. The arm is half an inch *shorter* than the other, and is closely approximated to the side: whenever abduction, flexion, or extension of it is attempted by the patient, the scapula invariably moves also. The patient has no power of rotation of the head of the humerus on the scapula, nor can any movement of the kind be communicated. The head of the humerus in this case has not been dislocated, but its tendency is certainly backwards towards the infraspinatus fossa, where some fulness is perceived. The partial absorption of the head of the humerus, as well as the removal of a portion of the surface of the glenoid cavity by caries, which we believe has occurred here, will sufficiently account for the shortened condition of the arm.

The most favourable prognosis we can form as to this case is, that a bony anchylosis of the shoulder joint will be established.

In the first of these cases (M. Moore) it was very manifest that the limb was elongated; and in this second case (Malloy), when the disease of the shoulder joint had arrived at a much more advanced stage, it was equally evident that the length of the affected extremity was diminished. We have adduced these cases as examples of what may be frequently expected to be seen by those who watch the course of articular caries of the shoulder joint; but we must be prepared to meet with examples in which it may be observed, that during the whole progress of the disease the length of the limb will be neither increased nor diminished. Varieties analogous to this we notice in the symptoms and progress of articular caries when it affects other joints (see Hip Joint); and therefore we need not be surprised, when the shoulder joint is the seat of chronic arthritis, that sometimes the extremity of the affected side is shorter, sometimes longer, and that sometimes during the whole course of the disease but little alteration as to increase or diminution of length is appreciable.

Anatomical characters of chronic arthritis of the shoulder.—The specimens we have an opportunity of examining anatomically, which show the ultimate effects of chronic arthritis on the several structures composing the shoulder joint, cannot be considered very rare; but it must be confessed that we seldom can ascertain the condition of the different structures of the shoulder joint which have been affected by chronic arthritis, excepting in cases in which the disease has arrived at its last stage, and has been the cause of the death of the patient. On making the post-mortem examination of the affected shoulder in cases where the disease has arrived at its last stage, we usually notice that the skin has been perforated by numerous fistulous openings; these are sometimes to be seen in the axilla, or ranged along the line of the margin of the deltoid muscle, perhaps at points more distant from the joint, as on the lower margin of the pectoral muscle near the mamma (case of Malloy). The subcutaneous cellular structure we have not found infiltrated, as it is in cases of white swelling of the knee, or of the other joints, with a gelatinous glairy matter; on the contrary, the cellular structure itself has always seemed to us to be in a wasted condition, containing no adeps; the deltoid as well as the articular muscles have been found in a state of atrophy. The bursa underneath the deltoid muscle has been observed to have been the seat of an effusion of fluid, quite distinct from that contained within the capsule of the joint; the internal surface of the bursa as well as the synovial lining of the fibrous capsule have been also found coated with lymph.

Sometimes in advanced cases the fibrous capsule has been found much contracted as well as thickened, and having numerous perforations in it, which had been the internal orifices of several fistulous canals, which having opened externally had acted as excretory ducts, as it were conducting purulent matter from the different points of the carious surfaces of the bones of the joint, and even from the centre of the diseased head of the humerus. In all of the advanced cases that we have examined, the *tendon of the biceps*, so far as its intra-articular portion is concerned, has been removed. The articular surfaces have been always divested of their cartilaginous incrustations, and the reticular structure of the head of the humerus, and of the scapula where it forms the glenoid cavity, usually exposed and bare sometimes coated with a layer of puriform lymph. Part of the head of the humerus has been removed, and in what remains of it deep digital depressions have been observed, and foramina, which penetrate even into the centre of the head of the bone.

M. Bonnet, of Lyons, states, "that on making the post-mortem examination of one

of his patients, who died of articular caries of the shoulder joint, he discovered, when a vertical section was made of the humerus, that in the centre of the head of this bone there was contained a cavity or cell, the size of a hazel nut, filled with tubercular matter, in the middle of which were found fragments of necrosed particles of bone. In this case also, he adds, tubercular matter was found in the axillary glands."* Bony nodules and stalactiform osseous productions are observed to be produced from different parts of the scapula and head of the humerus, in the vicinity of the shoulder joint. The coracoid process and acromial end of the clavicle we have found in these cases carious; the alterations of the osseous structure do not seem confined to the bones in the immediate vicinity of the joint itself. The whole scapula and humerus seem specifically lighter than they should be normally. We have tried the experiment of placing the diseased bones in water, and have seen them float, while the normal bones of the same region sink. The ribs, too, have been found sometimes carious simultaneously with the bones which constitute the scapulo-humeral joint.

These observations refer merely to the *local* condition of the articular structures themselves. The state of the constitution of many of these cases affected with chronic arthritis of the shoulder deserves the attentive consideration of the physician and surgeon.

The prognosis to be formed as to any advanced case of articular caries of the shoulder joint should be a guarded one, as the following facts may convince us. In the first case which we shall now adduce, fatal disease of the lungs seemed coincident with the articular caries of the shoulder; and at last it was doubtful which of the two diseases was the immediate cause of the death of the patient. In the second case disease of the brain, with paralysis, came on, and was the immediate cause of the death of the individual, who had been previously much reduced by articular caries of the shoulder.

Case 3. Chronic arthritis or articular caries of the shoulder joint, lasting thirteen months. —Matthew M'Cabe, a labourer, æt. 38, was admitted into the Richmond Hospital, Sept. 2. 1846, under Dr. Hutton's care.† He stated that about nine months previously he was seized with a pain in his left shoulder, which soon extended to his elbow; he was able to work for two months after the first attack of pain, but after this period the arm became stiff, and remained powerless by his side; the muscles around the shoulder and of the whole extremity were wasted; fistulous openings existed beneath the coracoid process, and through the deltoid muscle; the limb was of its normal length. When the joint was pressed the patient complained of pain; the motion of the head of the humerus on the glenoid cavity of the scapula appeared much limited; he had cough and hectic fever, of which the prominent symptoms, beside the cough, were a quick pulse and diarrhœa. He died Jan. 25. 1842.

Post-mortem examination.—The body was emaciated. Before making the examination, a plaster of Paris cast was taken of the left shoulder joint, which is preserved in the hospital museum: this shows especially the wasted condition of all the muscles around the shoulder joint, and the consequent prominence of the spine and acromial process of the scapula, usual in cases of articular caries of the shoulder. For the space of two inches along the anterior wall of the axilla and line of the humerus an oblong depressed scrofulous ulcer existed, in which were seen the orifices of three or four fistulous canals, which led from the interior of the joint. The elbow was placed somewhat backward, and the long axis of the humerus was consequently directed from below upwards and forwards; the convexity of the head of the humerus, without being dislocated, was placed somewhat more forwards and inwards than natural. Upon removing the deltoid muscle, which was wasted and perforated by fistulous openings, it was found that the capsular ligament was contracted and thickened, and had several openings in it, and that purulent matter was effused both into the joint and under the deltoid muscle, which thus formed the sac of an abscess. The cartilages had been entirely removed from the articular surfaces. The intra-capsular portion of the tendon of the biceps had disappeared; the highest part of this tendon which remained was attached to the inside of the capsular ligament. The bones had been injected with size and vermilion, and presented in their interior as well as on their carious surfaces a reddish colour; but they did not appear softened; when after maceration they had been dried, they seemed to be preternaturally light. The superior hemispherical portion of the head of the humerus had been removed very nearly to the level of the anatomical neck, or situation for the attachment of the capsules; and the surface was red, porous, and much roughened from caries. Towards the highest part of the humerus, just within the line which separates the great tuberosity from the head of the humerus, there existed two very deep digital or alveolar depressions, which penetrated into the cellular structure of the head of the humerus: the anterior part of the upper extremity of this bone, where the bicipital groove exists, was rough and porous; the groove was much deepened, particularly in the situation of the lesser tuberosity, which was elevated into a bony nodule, and enlarged about one inch below the lesser tuberosity. On the front of the surgical neck there existed another bony nodule, but smaller.

The surface of the glenoid cavity seemed to have been somewhat worn away and rendered more than naturally concave; the anterior or inner margin of it was rounded off by caries. The oval outline of the glenoid cavity was elongated from above downwards, and somewhat

* Traité des Maladies des Articulations.

† The writer is indebted to Dr. Hutton for the notes of this case.

narrowed transversely. The axillary margin of the scapula, where the long head of the triceps arises, was furnished with the friable stalactiform osseous productions, which we have already noticed to have existed around the articular surfaces of all the other articulations, when they had been for a long time the seat of strumous arthritis, or scrofulous caries of the joint.* The rest of the scapula had a rough scabrous aspect; the coracoid process presented the appearance also of having been in a commencing state of caries. The external lamina of the bone had been absorbed; the exposed reticular structures of it were so friable, they would crumble under the slightest pressure.†

The lungs presented the ordinary appearances of phthisis in its last stage; there were tubercles and tubercular excavations in both lungs.

In this case the disease of the shoulder joint seemed to have arrived at its last stage, and to have been in itself sufficient to have induced a fatal hectic fever. However, coincident with the articular caries appeared the disease of the lung, which caused, or at all events hastened, the death of the patient.

Case 4. Articular caries of the shoulder in the fourth stage.‡—Edward Brady, æt. 36, a baker, was admitted into the Richmond Hospital, 6th of May, 1828, labouring under disease of the right shoulder joint. It appeared that he had had for some time previously a chronic inflammatory affection of this articulation, for the origin of which he knew no cause; that an abscess had formed, and that matter had made its way through the skin just beneath the point of insertion of the pectoralis major into the humerus, where a fistulous aperture existed, which daily gave exit to a considerable discharge of purulent matter. On admission into the hospital, the right shoulder joint was swollen, the man was emaciated and in a state of debility, his pulse quick and weak; he complained of pain when the slightest pressure was made on the joint, or motion communicated to it. From the short notes of the patient's symptoms during the two last months of his life when in hospital, we learn, that after five weeks' treatment, such as local bleeding and counter-irritations, as blisters, &c., he was not really better. On the contrary, "the patient was much debilitated, the hectic symptoms had increased, the shoulder was flattened, the motions of the joint were circumscribed within very narrow limits, the acromion was prominent as in axillary dislocation." In another month, viz. July 12, we find entered the following report: — "No improvement either locally or constitutionally; the shoulder is more emaciated, and a crepitating, grating sound is elicited on rotating the humerus; the *hand is slightly œdematous*, yet the discharge is less profuse, and considered of a more healthy appearance." Eight days subsequently to this report the patient became comatose, and died in the course of a few hours.

Post-mortem examination. — The subcutaneous cellular structure which covered the deltoid muscle of the affected side was destitute of all adipose tissue; the deltoid was pale and thin; the sub-deltoid bursa contained a sanious fluid, which being removed it was seen that the bursa had been lined with lymph; the fibrous capsule, ulcerated at one point, was thickened, as was the synovial membrane, which was pulpy; the articular cartilage was entirely removed from the head of the humerus and surface of the glenoid cavity of the scapula. The superior extremity of the former was almost totally destroyed, the bone having been crumbled down into many small portions. The surfaces were covered with unhealthy looking pus and lymph. The long tendon of the biceps had disappeared; the surface of the glenoid cavity was carious; the small muscles about the joint resembled the deltoid as to the state of thinness and atrophy they had been reduced to. The sinus leading to the point in the axilla already mentioned was lined with lymph.

The disease of the shoulder joint in this case, it appears, had, as in the preceding, arrived nearly at its last period, and we might have supposed that the morbid state here described of so important an articulation was of itself sufficient to cause a fatal result, when the affection of the brain suddenly supervened, and became the immediate cause of the death of the patient.

It were very desirable that we could assign to the four periods of this disease of the shoulder joint, when affected by chronic arthritis, the anatomical characters which belong to each stage respectively; but we repeat, we are as yet only truly acquainted with those appearances which the post-mortem examinations exhibit of the *ultimate* result of the disease as it has affected the articular textures, when it has been the cause of the death of the patient.

The pathological condition, therefore, of the different tissues which enter into the composition of the shoulder joint, as they are affected in the early stages of this chronic disease, is as yet, we believe, but little known. The most remarkable features of the second stage of chronic arthritis of the shoulder joint we notice, is the descent of the head of the humerus from the glenoid cavity, and consequent elongation of the upper extremity of the affected side. This, we conjecture, may be accounted for by recollecting that the deltoid and articular muscles, which in their normal state maintain the head of the humerus close up against the glenoid cavity, are now in a state of atrophy. They have from want of use, and perhaps, also, from sympathy with the diseased state of the articular structures, lost all tonic force. Although these muscles are not really paralysed, still they seem not to have

* Vide Hip Joint, Abnormal Condition of, Vol. II. p. 794. *fig.* 311.

† Museum, Richmond Hospital.

‡ This case has been extracted from the case book of the late Dr. Macdowell, whose accuracy of observation and fidelity were well known to the editor of this work as well as to the writer.

power enough to resist the influence of the weight of the upper extremity; and hence the head of the humerus, unrestrained by the naturally loose capsular ligament, descends to the extent of half an inch or an inch from the glenoid cavity. There can be but little doubt, also, that in the second period of the disease we are now considering, an effusion takes place into the interior of the synovial capsule of the joint: this may be altered synovial fluid or lymph, or purulent matter to a small amount; but whatever the effusion be, it also will have the effect of partially displacing, and causing an elongation of, the upper extremity.

It may be asked how it happens that the head of the humerus, once partially displaced downwards, does not become subjected to a secondary displacement inwards, under the influence of the contractions of the pectoral and other muscles? The answer may perhaps be, that, in the second stage of this disease, the long tendon of the biceps retains its form, place, and functions; so long as this tendon remains in its state of integrity, arching over the head of the bone, and then passing in a perpendicular line down along the humerus, the head of this bone cannot be partially elevated above its normal situation, nor even drawn inwards or backwards by either of the great muscles which form the anterior or posterior walls of the axilla; but when the long tendon of the biceps is destroyed, as it very generally is in the third stage of this disease, then the head of the humerus may be moved in whatever direction the inclination of the new plane formed by the altered surface of the glenoid cavity may give, or the muscles may draw it in.

In the third stage of chronic arthritis of the shoulder, the bones which compose the joint are carious, and their surfaces are partially and unequally removed; the length of the extremity may be diminished. The long tendon of the biceps is removed, and hence no longer influences the position which the head of the humerus is ultimately to take, whether the bone in this third stage be partially displaced upwards, forwards, or backwards.

Some of the surrounding muscles are in this period of the disease in a state of atrophy, while others retain their form and functions. The proper articular muscles, whose normal function it is to keep the head of the humerus close to the glenoid cavity, are, in the third stage of disease, wasted; and besides, as their capsular attachment is usually in this advanced stage of the disease destroyed, their influence becomes annihilated.

The pectoralis major may draw the head of the bone towards the median line anteriorly; the latissimus dorsi and triceps posteriorly towards the dorsum of the scapula; and several muscles, such as the attenuated deltoid, the coraco-brachialis, &c., may elevate the head of the humerus, so as to bring its upper surface into contact with the acromion and coracoid process.

We cannot *pretend* to say what it is which determines the line of direction the head of the humerus in these partial displacements which occur from disease may take, or explain why the bone should in some cases take one direction, and why occasionally another; no more than we can assign any cause for the various directions the head of the femur takes in the third stage of scrofulous caries of the hip joint, a disease we consider analogous to this we are now considering.

Anchylosis of the shoulder joint.—Anchylosis of the shoulder joint may be observed to be one of the terminations of an attack of acute or chronic arthritis of this joint. It may, we think, be remarked generally as the result of true bony anchylosis of any of the joints of an extremity, that shortening of the limb shall have taken place. This observation seems to be exemplified by what we commonly observe in studying the characters of true bony anchylosis of the shoulder joint. Most of the specimens preserved in our collection at the Richmond Hospital museum and elsewhere, present examples of solid union of the bones which compose the shoulder joint; partial displacement upwards of the head of the humerus, and slight shortening of the extremity having previously taken place. There is at present in the museum of the Richmond Hospital a specimen of complete bony anchylosis of the shoulder joint, which was exhibited by Dr. R. Smith to the Pathological Society on the 13th March, 1841, along with some other examples of anchylosis of this joint. "The specimen," observes Dr. Smith, "was taken from the body of an individual aged 90, who had been confined to bed for many years before his death. The *external* appearance of the shoulder joint resembled somewhat those of luxation of the head of the humerus into the axilla, so far as the acromion process having been prominent, and the joint in the region of the deltoid completely flattened; the arm was rotated inwards; the glenoid cavity and head of the humerus formed one continuous bone; the greater tubercle was anchylosed by bone to the acromion process, while the coracoid process was similarly joined to the lesser tubercle." Consequently the humerus must have been partially displaced upwards, and the arm shortened. The supra-spinatus and infra-spinatus muscles, as well as the subscapularis, had undergone fatty degeneration from want of use; a change very commonly observed in cases of true anchylosis of long standing, no matter which of the joints has been the seat of this termination of arthritis. In the example just adduced the humerus was observed to have ascended, and the greater and lesser tuberosities had formed a solid union with the coracoid and acromion process; but in some examples the anchylosis has been found to have taken place directly between the surface of the glenoid cavity and the head of the humerus; and a vertical section of the bony structures running through the consolidated joint exhibited the cells of the original head of the humerus and the diploe of the scapula

freely communicating with each other, just as we have already noticed as exemplified in complete bony anchylosis of the hip joint (see Vol. II. of this work, p. 796.). It may not be uninteresting to transfer our attention from the appearances disclosed by the post-mortem examination of an anchylosis of the shoulder joint to the signs by which we recognise this state of the articulation in the living.

A labourer, Thomas Rooney, æt. 24, appeared among the extern patients at the Richmond Hospital on Thursday, 8th June, 1848, seeking relief for some internal ailment; we noticed the wasted condition of the right shoulder joint. We learned that about three years previously he had fallen on the right shoulder and injured it; he applied for relief to an ignorant person called a bone setter, in whose hands he suffered severely, having been subjected to violent dragging, with the view, as he was told, of reducing a supposed dislocation of his shoulder; violent inflammation of the joint succeeded, for the treatment of which he was admitted into Steeven's Hospital. While in the house suppuration of the joint occurred, and purulent matter made an exit beneath the anterior fold of the axilla, where the tendon of the pectoralis major is inserted into the humerus. The pain and swelling then became less, and he returned to the country, the abcess and sinus leading from it closed up, and his general health became gradually as good as it had been before he met with the accident, and remained so until he became affected with the trivial ailment he now sought advice for as an extern patient at the Richmond Hospital.

The shoulder joint, on a *superficial* examination, might be said to resemble somewhat the appearance presented in a case of an old unreduced axillary dislocation, but the resemblance was but slight. It is true that the acromion process stood out laterally, that the deltoid was flattened, that the anterior fold of the axilla was deeper than natural, and that the angular appearance the right shoulder presented was strongly contrasted with the natural rounded contour of the left shoulder joint; but the head of the humerus could be felt underneath the acromion process; the elbow, instead of being separated from the side as in disolcation, seemed habitually approximated to it. The biceps muscle, in consequence of the atrophied condition of the elevators of the extremities, had double duty to perform, and hence had been greatly hypertrophied at its lower part. The man can hold the plough, and can perform all the under movements of the arm very well, but cannot elevate it, nor place his forearm behind his loins.

In this case the arm is habitually approximated to the side, directed somewhat forwards, and strongly rotated inwards. The most striking features in the case are the wasted condition of the shoulder joint from the atrophy of the deltoid and articular muscles, and the extraordinary development of the lower part of the belly of the biceps the cause of which hypertrophy is easily understood.

We have seen cases in the living subject of perfect anchylosis of the shoulder joint, in which it seemed doubtful whether any shortening of the extremity existed. In these cases we must suppose that the head of the humerus became directly consolidated with the surface of the glenoid cavity, and without the more usual union having been established between the upper extremity of the bone and the superincumbent processes.

One of the most important points which engages the attention of the practical surgeon, in the treatment of cases of diseased joints at the period when it is expected that a process of anchylosis is going on, is to preserve the affected limb in that position which will be found most convenient to the patient, when true bony anchylosis of the joint shall have been established; for example, under such circumstances we take care to preserve the knee and hip joints extended, the ankle and elbow joint bent to a right angle; but the shoulder joint, when anchylosis is taking place, may be left to nature, so far as the position of the limb is concerned, because the humerus in these cases habitually remains nearly parallel to the long axis of the body, somewhat rotated inwards; and, in a word, in a position which will be found most favourable to the performance of those functions it shall be called upon to execute when the scapulo-humeral joint is in an anchylosed state.

Chronic rheumatic arthritis of the shoulder joint.—The shoulder joint is sometimes the seat of this peculiar disease, though by no means so frequently as many of the other articulations. The origin of it we have known to be attributed to accident, such as a fall on the shoulder, or to a sprain of the joint. On some occasions the sudden exposure of the person, when overheated, to currents of cold air, has been referred to as its cause; and in others the chronic disease of the shoulder joint has been supposed to have originated in the lingering remains of a rheumatic fever. These are, indeed, the ordinary exciting causes of this disease in general, no matter in what particular joint it may show itself.

Symptoms. — The patient complains of feeling pains in the shoulder joint, which, like those of rheumatism, are variable, and seem to be under the influence of changes in the atmosphere. He states that he feels a stiffness in the joint, and is conscious of a "crackling" sensation in it, particularly when he first moves it in the morning. The muscles around the articulation fall into a state of atrophy, while the bony prominences around the joint generally become conspicuous from their enlargement.

If only one shoulder joint be affected with the ordinary form of the disease, and we compare it with that of the opposite side, the head of the humerus of the affected side will

be observed to be somewhat elevated, advanced, and very generally approximated towards the middle line. When we view the articulation in profile (as it were), the amount of the advancement of the head of the humerus is more readily appreciated. And when we look at the shoulder joint from behind, a very remarkable abnormal depression may be seen, which corresponds to the space or interval which exists between the posterior part of the glenoid cavity and the head of the humerus. After a time, the voluntary motions of the joint become restricted within very narrow limits. The patient cannot well abduct the elbow from his side, nor elevate it nearly to an horizontal level. The motions he is himself capable of communicating to his arm are chiefly confined to under movements, yet the head of the humerus is in some of these cases susceptible of an abnormal degree of mobility. Although in the ordinary form of this disease the head of the humerus will be found to be placed above its normal level, and is observed to be several lines higher than the coracoid process, still if the arm be grasped by the surgeon it can be drawn down, and the head of the bone will place itself beneath the coracoid process; the joint will then assume all the appearances usually assigned as the marks of the case styled by Sir A. Cooper "Partial luxation of the head of the humerus forwards and inwards." In cases of long standing, the capsular ligament becomes wider than natural, and the articular surfaces are so altered that partial dislocation of the head of the humerus occurs in other directions besides those above alluded to; but any observations we have to offer upon this part of our subject it will be more convenient to defer until we come to speak of the *anatomical* characters of this disease.

Although the patient may complain of pain in the middle of the arm, and of spasms of the muscles, of the whole extremity of the affected side, even to the fingers, yet if the surgeon elevate the arm at the elbow, and press the humerus even rudely against the glenoid cavity of the affected articulation, the patient experiences no *uneasiness*.

It is very remarkable that this peculiar affection of the shoulder joint has never, as far as we have known, terminated in anchylosis, nor proceeded to suppuration; nor has its presence excited any sympathetic disturbance in the constitution of the patient; yet from year to year the disease slowly but gradually increases, until the patient is carried off by some other complaint, or dies from the mere effect of age alone.

Diagnosis.—This peculiar affection of the shoulder joint, particularly when the history of the case is known, cannot well be confounded with any other disease of the articulation with which we are acquainted. Scrofulous caries of the bones of the shoulder joint may have some symptoms in common with the chronic disease we are describing, but there is more pain and more wasting of the muscles of the arm and fore-arm, and more sympathetic disturbance of the constitution in the case of articular caries of the shoulder than in that of chronic rheumatic arthritis of this articulation; and while the former case usually proceeds to suppuration, or to anchylosis of the joint, these processes never take place in the latter.

In the chronic rheumatic disease, the opposite shoulder joint will, in general, be found symmetrically affected; a circumstance we have never yet known to have been the case in a chronic arthritis, or articular caries, of the shoulder.

The history of the case of chronic rheumatic arthritis usually betrays its nature by the general rheumatic pains the patient reports himself to have suffered from; by the disease not being confined to the one articulation; by the enlargement of the bony prominences about the joint, although the muscles are wasted. In both cases there may be crepitus felt on moving the joint and on making pressure; but the efforts to elicit crepitus, and the pressing together of the articular surfaces cause, in the case of chronic arthritis, or articular caries, so much pain, that the patient shrinks back from our attempts at making these trials; while in the ordinary case of chronic rheumatic arthritis of the shoulder, when even it appears as a local disease confined to one or two articulations, we find we can even rudely press the head of the humerus against the surface of the glenoid cavity without causing the patient pain, just as we can, in the case of the same disease when it affects the hip joint, press the head of the femur against the acetabulum without causing the least uneasiness to the patient (see Vol. II. p. 799.).

No doubt some few cases of chronic rheumatic arthritis of the shoulder joint in the living and in the dead have been mistaken for *partial dislocation of the head of the humerus, the result of accident*; but we are of opinion that, as the chronic rheumatic affection is daily becoming better known to the profession than formerly, such errors will no longer be committed, particularly when the anatomical characters of this disease have been more fully studied by the profession.

Anatomical characters. — When we anatomically examine the shoulder joint of a patient who has long laboured under this chronic disease in the articulation, we notice on removing the integuments that the deltoid muscle is unusually pale, and that the interstices between its fibres are occupied by an unhealthy-looking fat. This and the subjacent capsular muscles are in a state of atrophy. The capsular ligament is generally altered in form and structure, and it will be sometimes found to have abnormal attachments above to the acromion or coracoid process; and, below, its attachment to the anatomical neck of the humerus is sometimes partially interrupted, allowing of an interval which in some forms of the disease permits the head of the humerus to pass through it.

The capsular ligament is occasionally increased in thickness, and its fibres are hypertrophied; and it is generally more capacious than natural, showing that effusion of synovia to a considerable amount had existed, although the external signs of this phenomenon are not usually evident. When the interior of the synovial sac is examined, it will be found to present evidences of having been the seat of chronic inflammation. Bunches of long organised fringes hang into the interior of the synovial sac; and many of these vascular fimbriæ, which in the recent state are of an extremely red colour, surround the corona of the head of the humerus. We also notice rounded cartilaginous productions, appended by means of membranous threads attached to the interior of the various structures which compose the joint. Some of these foreign bodies are small, others large. Some are round; but their shapes are various. Besides these rounded cartilaginous bodies, we occasionally find osseous productions of a multangular form added to the edges of the glenoid cavity, deepening it, and increasing the articular surface for the reception of the head of the humerus, which usually is in such cases much enlarged.

The intra-articular part of the long tendon of the biceps is very seldom to be seen in the interior of the joint; but immediately *outside* of the capsular ligament the latter tendon will generally be found to have contracted a firm adhesion to the superior extremity of the bicipital groove (*fig*. 428. *a*.).

Bones.—The head of the humerus assumes a very characteristic appearance as a consequence of this peculiar disease, and acquires a form which cannot be easily mistaken for the effects of any other disease or accident. The usual angle at which the head and neck of the humerus join the shaft of the bone is often altogether effaced; so that instead of the axis of the head and neck of the humerus being directed, as it normally is, upwards, inwards, and backwards, it seems to run vertically, or, as it were, in a continuous line with that of the shaft of the bone. The articular surface is usually much enlarged, and in the ordinary form of this disease occupies the whole summit of the humerus, extending itself even over the greater and lesser tuberosities and the highest part of the bicipital groove; effacing in this direction part of the circular line which marks the anatomical neck of the humerus and insertion of the capsular ligaments. Some of the articular cartilage is removed from the head of the bone, which, in some places, presents a porous appearance (*fig*. 428.).

In other parts, in place of the cartilage, there is a polished ivory-like surface. The portion of the bone which thus presents this polished surface is the very summit of the humerus; and this is the part of the bone which will be found evidently to have been for years in habitual contact with the under surface of the acromion and coracoid process, where these bones assist in forming portions of the new and abnormal cavity for the reception of the head of the humerus. The

Fig. 428.

Chronic rheumatic arthritis : a, tendon of the biceps

basis of the head, in the line where it joins the shaft of the humerus, is studded round by granular osseous productions, which give to it a characteristic appearance (*fig*. 428.). By these vegetations of bone, we are reminded of the analogous appearance which the corona of the head of the femur presents when affected by the same species of morbid action *; but of course much variety may be expected to be found in the form the head of the humerus will assume under the influence of this disease: we have found the articular surface in some cases formed completely on the summit of the humerus, sometimes on the side of the head. Very generally the head of this bone is much enlarged, but exceptions to this rule occur. One of the most remarkable alterations of form we have noticed as the result (as we imagine) of this disease we found in the anatomical museum at Leyden. In the specimen to which we allude, the head of the humerus appears bifurcated at its upper part, or divided longitudinally into two surfaces for articulation with the scapula.†

Lastly, we have to advert to the anatomical characters of the new and abnormal socket formed for the reception of the altered head of the humerus. This new cavity is composed of two portions, which however will be found to have become almost continuous with each other. The original glenoid cavity (generally much enlarged) forms one of these portions; the coraco-acromial vault the other.

* Vol. II. *fig*. 317. page 802.

† Sandifort in his fourth volume has given a delineation of the head of the humerus in this case as well as of the scapula the glenoid cavity of which was enlarged very much in the direction downwards, and was surrounded with a margin of osseous granules.

By the coraco-acromial vault we mean a concave surface, looking downwards, formed internally by the coracoid process, and externally by the acromion; the intervening space being filled up in front by the proper triangular ligament of the scapula, and completed behind by a portion of the under-surface of the acromial end of the clavicle This coraco-acromial arch in the normal state overhangs much the head of the humerus, and its inferior surface is not articular, but, on the contrary, is separated from the head of the humerus, which is beneath it, by an interval of about three or four lines, measured in vertical height. This interval is normally occupied by the long tendon of the biceps and the capsular ligament, as they pass from the upper margin of the glenoid cavity to the humerus —the capsular ligament having above it the tendon of the supra-spinatus, a special bursa mucosa, much cellular tissue, and the fibrous bands, which pass from the humerus to the coracoid and acromial processes.

Under the influence of the most usual form of this disease, all these parts intervening between the head of the humerus and the coraco-acromial arch or vault are absorbed; and the superior extremity of the head of the humerus at length comes into immediate contact with the concavity of the arch. The first effect of this morbid process in bringing about the remarkable changes which we have been describing, may be to cause the absorption of those tendons, viz. the supra-spinatus and the long tendon of the biceps, which pass over the head of the humerus, and which, by virtue of their muscular attachments, restrain within proper limits the degree of elevation * which the head of the humerus is normally susceptible of. When, however, these tendons are absorbed, and consequently the muscles to which they belong have lost all power of repressing the humerus, the latter is then dragged upwards, and its head being constantly pressed against the under-surface or concavity of the coraco-acromial arch, not only do the processes of the scapula which form this arch at length show manifestly the effects of friction, but the outer portion of the acromial end of the clavicle does so equally. All these portions of bone are rendered concave, and are usually covered by a porcelain-like deposit, corresponding to an analogous polished surface which covers the convexity of the summit of the humerus. In many cases in which the shoulder joint has long been the seat of this chronic disease, the *acromion process* has been found traversed in the line of junction of its epiphysis, by a complete interruption of its continuity, *as if fractured:* we say as if fractured, for we are convinced that this solution of continuity of the acromion process is not really a fracture produced by violence, but a lesion, which so frequently exists in combination with chronic rheumatic arthritis of the shoulder, that we are compelled to look upon it, in these cases, as a peculiar organic change, the result of chronic rheumatic disease. We do not pretend to account for the separation of the acromion process into two portions; nor can we say why it is that the division usually occurs in the original line of the epiphysis, particularly at the late period of life at which we generally witness this phenomenon. In some of these cases we have found the acromion in a state of hypertrophy; in others in a state of atrophy; but in no case did there seem to be any attempt at ossific deposition on the contiguous surface of the separated portions of the acromion, a circumstance which might be expected if a fracture had occurred.

* If the long tendon of the biceps be dislocated and thrown inwards over the head of the humerus, the same effects will be produced as if it were absorbed.

The glenoid cavity of the scapula, under the influence of this disease, is generally much enlarged; and by becoming wider above, it loses much of its ordinary ovoidal figure, approaching in its outline more to a circular form. The surface of the cavity appears preternaturally excavated, its brim being elevated into a sharp margin. The cartilage of incrustation, as well as the glenoid ligament, are generally removed altogether, some parts of the surface are porous, and some covered with porcelain-like enamel. Near the margins of the glenoid cavity, where the capsular ligament arises, we may often find osseous productions attached to the capsular ligament, adding depth to the receptacle for the enlarged head of the humerus. The glenoid cavity will of course be found to present much variety of form. Sometimes the head of the humerus occupies its upper portion, and habitually remains in contact with the under surface of the acromion and coracoid process, thus leaving the lower part of the glenoid cavity unoccupied.

Sometimes part of the head of the humerus remains within the glenoid cavity, while the remaining portion of it occupies the neighbouring part of the subscapular fossa. Occasionally the head of the humerus will be found to have descended on the axillary margin of the scapula *; while in other cases equally rare, which we shall hereafter have occasion to refer to, the head of this bone may, under the influence of this disease, pass backwards on the dorsum of the scapula: under all these circumstances, the glenoid cavity must undergo special changes of form adapted to each variety.

Those who carefully study the anatomical characters of chronic rheumatic arthritis of the shoulder, cannot fail in the course of their investigation to observe many deviations from the normal state of the joint, the result of this disease, which are well calculated to mislead those who are unacquainted with it; to which we may here advantageously advert.

It has been repeatedly remarked, that one of the most constant anatomical observations we had to make in post-mortem examinations of the shoulder joints of those who had been

* Catalogue of the Museum of the College of Surgeons, Dublin, vol. i. p. 399. Prepar. E. b. 905.

affected with chronic rheumatic arthritis was, that the long intra-articular portion of the tendon of the biceps was absent from the joint, although adherent outside to the highest point of the bicipital groove (*fig.* 428.). This removal of a large portion of the tendon of the biceps strikes the observer who is unacquainted with this disease as a direct proof that the tendon had been *ruptured* by accidental violence, and that a partial luxation of the head of the humerus has been the consequence.

Another character of this disease is, that the humerus has a very general tendency to pass *upwards* towards the coraco-acromial vault; and besides the removal of the tendon of the biceps, the superior part of the capsular ligament is observed to be deficient. Those who do not know that this perforation is a consequence of slow disease, immediately take it for granted that the same accident which ruptured the tendon of the biceps had also caused the head of the humerus to be partially dislocated upwards, perforating as it passed the superior part of the capsular ligament.

If, in addition to these abnormal appearances, small portions of bone, as if fragments broken off from the margins of the glenoid cavity, are found to be present, as they frequently are, this also is an appearance calculated to confirm an erroneous impression, that some external violence has been the source of it; and if in addition the acromion process be found divided into two portions, as we have frequently noticed it, the prejudice in the observer's mind may at first be strongly in favour of the idea, that accidental violence has been the source of these many and combined phenomena.

But notwithstanding all these lesions, namely, the total disappearance of the articular part of the tendon of the biceps; the perforation of the superior part of the capsular ligament by the head of the humerus, and the separation into two portions of the acromion process, we feel convinced that all these phenomena combined should by no means be considered as proof of any accident having occurred to produce them; but, on the contrary, should be looked upon as the usual result of chronic rheumatic arthritis of the shoulder.

The tendon of the biceps in all those cases of presumed accidents is said to be *ruptured;* yet the chronic disease of the shoulder joint is frequently found to affect both shoulder joints in the same individual, and the long tendon of the biceps, in these cases, to be removed on *both* sides. It is easy to conceive that this double lesion may be the effect of disease, but difficult to imagine how any accidents could occur to "rupture" the tendons of the biceps in *both* shoulder joints. Nor is it easy to admit that the long tendon of the biceps can be readily ruptured in *partial* dislocations of the humerus from accident, when we know that this tendon is rarely if ever ruptured, even in *complete* luxation of this bone. The statement made in the report of various cases in surgical works, and in the catalogues of museums, in which we find it briefly noted, "that the tendon of the biceps was found ruptured," has been made by the writers confessedly without any knowledge of the previous history of the case, the anatomical characters of which they are describing. On this account we feel the less delicacy, after long and patient consideration of the subject, in expressing our conviction that the tendon of the biceps, in the numerous cases published, was not (as supposed to be) *ruptured* by accident, but absorbed as the result of disease.

We have stated that the bones entering into the formation of the shoulder joints are very generally enlarged as a consequence of this chronic disease having for a considerable time existed in the articulation. It is right, however, here to observe, that very extensive inquiry into the pathological anatomy of this peculiar affection as it presents itself in the shoulder joint, will prove that some few exceptions to this rule may be occasionally met with; and that, instead of the bones entering into the formation of the shoulder joint being found hypertrophied, they may be discovered, on the contrary, to be in a state of atrophy; or portions of these bones may be removed altogether, as the apparent result of this chronic rheumatic disease.

That the writer may not appear to have been singular in having observed the changes which the acromion process and neighbouring bones have undergone as the result of this chronic rheumatic disease, he may refer to the dissection of a case mentioned by Cruveilhier, in which the affection we have called chronic rheumatic arthritis was so general that there was scarcely any articulation in the body exempted from its effects. When adverting to the anatomical changes observable in the region of the shoulder in this example, he says, the external extremity of the clavicle and the neighbouring part of the acromion were in a great part destroyed, &c.*

In the museum of the College of Surgeons in Dublin will be found a preparation of a shoulder joint, which is styled by the late Dr. Houston in his catalogue, a specimen of chronic rheumatic arthritis of the shoulder; and that it was justly so styled may also be inferred from the "bunches of synovial fimbriæ," which hung into the synovial cavity of the joint; the existence of hydrops articuli, or over-distension of the synovial sac by an albuminous fluid; and from the deficiency of the *intra-articular portion of the tendon of the biceps,* mentioned in the account given of this case: — all these show the disease to have been correctly designated. The writer finds upon examining this preparation with the intelligent curator, Mr. Carte, that the acromial end of the clavicle is unsupported, and that the acromion process has been removed for the amount of an inch in extent; that which remains for this process

* Cruveilhier, livraison ix. p. 12.

is thinner than natural, and in a state of atrophy.*

The *coracoid process* is not usually found so much altered by the existence of this peculiar disease in the shoulder joint as the acromion; but we have found its under concave surface in some cases to have entered into the formation of the shoulder joint, and to have presented a broad glenoid-shaped surface, which had been smoothed off from frequent contact with the head of the humerus, while the breadth of the process had been at the same time much increased.

We have thought it necessary to enter into this subject thus minutely, because we are convinced that, up to the present hour, these remarkable appearances, when met with, have been misunderstood even by some of the most intelligent anatomists and physicians. This circumstance may appear perhaps capable of explanation, by recollecting that the disease generally runs a long course, is not in itself fatal; and hence, although the practical medical man may have had numerous opportunities of witnessing the symptoms of this disease in the living, he may never have had any opportunity in any case of informing himself of the true relation subsisting between the symptoms of this disease of the shoulder joint as observed in the living patient, and the phenomena which the *post-mortem* examination of the same shoulder joint might have presented. On the other hand, when anatomists have heretofore discovered in dissection appearances which are stated to be truly those of chronic rheumatic arthritis of the shoulder, they have not at that time been able to learn the previous history of the case.

The following case may contribute somewhat to supply this deficiency :—

Case. Chronic rheumatic arthritis of the shoulder. — J. Byrne, a servant, æt. 55, was admitted into the Whitworth Hospital House of Industry in 1834. Dr. Mayne, at that time resident clinical clerk in the hospital, informed the writer that, besides the disease of the lungs, for which the man was admitted, he also had an affection of the right shoulder joint, which presented all the characters attributed to the case of partial luxation of the humerus, and was kind enough to invite the writer to examine him.

The man complained of an inability to use his right arm well, in consequence of his having for some years an affection of his right shoulder joint, in which he felt almost continually a dull boring pain. He could however perform, without much inconvenience, all those motions of the arm which did not require it to be raised near to the horizontal line. The joint felt to his own sensation somewhat stiff; and he was conscious, under certain movements of the arm, of a sense of something crepitating or crackling in the joint. Upon viewing the shoulder in front, it had a wasted appearance; the acromion process was more prominent, rendering the bony eminences around very conspicuous; the head of the humerus seemed to be a little higher than usual, and to have advanced somewhat forwards. The amount of advance was best seen by viewing the joint in profile or laterally. In this aspect a slight elevation and the increase of the antero-posterior measurement of the joint became very obvious. When the arm was pressed by the surgeon, and very slight force used, the humerus could be easily made to descend somewhat, and at the same time to pass a little beneath the outer margin of the coracoid process ; and the finger could be readily pressed into the outer half of the glenoid cavity, into the space which the head of the humerus was found to have abandoned. When again the shaft of the humerus was elevated vertically, its superior extremity could be felt to strike against the under surface of the acromion. In a word, the symptoms strongly resembled those usually assigned to the partial luxation forwards and inwards.

This patient remained in the Whitworth Hospital until the pulmonary affection proved fatal. Dr. Mayne and the writer carefully examined the joint, which is still preserved in the museum of the Richmond School (*fig.* 429.).

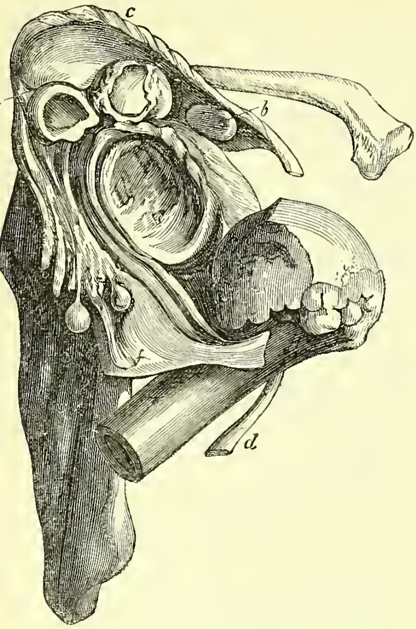
We found the deltoid and other muscles around the joint in a wasted condition, and much paler than those of the opposite shoulder. When the capsular ligament was exposed, it was found to have superiorly a much wider and more extensive adhesion than natural. Instead of this fibro-synovial sac having its ordinary attachment all round to the limited circumference of the glenoid cavity of the scapula, its adhesion to the upper margin of this cavity did not exist, but the superior and outer portions of the capsular ligaments seemed to have acquired new attachments, and to be connected superiorly and externally with the anterior margin of the coraco-acromial arch ; and thus the space in which the head of the humerus had been permitted to move, had been rendered much more extensive than natural.

The capsular ligament was much thickened, and when opened more synovia than usual flowed out. This membrane was lined with cellular flocculi, and several small cartilaginous bodies, rounded, and of the size of ordinary peas, were seen to float in the interior of the synovial sac, appended by means of fine membranous threads. All those parts which, in the normal condition, intervene between the superior part of the head of the humerus and under surface of the coraco-acromial arch, were completely removed. No remnant or trace of the supra-spinatus tendon, nor any portion of the capsular ligament to which this tendon is attached, was to be found. The entire of the articular portion of the tendon of the biceps was absent, and the highest point of the remaining portion of the tendon was attached to the summit of the

* See a preparation in the Museum of the College of Surgeons, Dublin, Catalogue, vol. ii. p. 397. E. 6. 901.

bicipital groove. It was remarkable that the acromion process and other portions of bone,

Fig. 429.



Case of J. Byrne. — Chronic rheumatic arthritis.

a, line of complete division of the acromion into two portions; *b*, coracoid process; *c*, acromial end of the clavicle, worn by the attrition of the head of the humerus; *d*, tendon of the biceps adherent to the bone; *e*, glenoid cavity ; *f*, capsule widened; foreign bodies attached to it.

viz. the outer extremity of the clavicle and coracoid process, had *acquired size and density*, although their under surfaces were much worn and excavated where they formed an arch which overhung the humerus. These appearances showed the great degree of friction and pressure from below upwards which these bones had been subjected to, from the head of the humerus being constantly drawn upwards by muscular action. We also noticed that the *acromion process was traversed from within outwards* by a perfect solution of continuity, completely dividing it into two nearly equal portions. This might be supposed by some to have been a fracture which never had been united by bone — an opinion which, however, we did not entertain; the two pieces of the acromion were on a perfect and uniform level, and the edges of the separated portions of bone exhibited no evidence of any ossific deposit, nor any such appearances as would lead us to infer that a fracture had existed.

The glenoid cavity of the scapula was larger and deeper, and more of a cup-like form than usual. The cartilage of encrustation and glenoid ligament were removed, the surface of the cavity presented a porous appearance. Along its inner margin were arranged several round and firm cartilaginous granules.

The head of the humerus was somewhat enlarged. The articular surface had become extended over the superior margin of the greater and lesser tuberosity. Much of the cartilaginous investment of the head of the bone had been removed, and its place supplied by means of a porcelain-like deposit. The line which marks the junction of the head of the bone to the shaft, was studded all round with granular elevations of bone (*fig.* 429.).

Our knowledge of the anatomical characters of this disease has now arrived at a degree of precision quite sufficient, we might suppose, to save us henceforth from falling into the error of confounding the morbid results of chronic rheumatic arthritis of the shoulder with the consequences of chronic or acute osteitis, or with the ultimate effects of accidents sustained during the patient's lifetime. Nevertheless we feel called upon now to allude to some cases of *partial luxation* of the shoulder joint which have been published as the result of accident, but which we consider to be specimens of the chronic rheumatic disease of the shoulder joint which we are endeavouring to describe.

Among these authors we find Sir A. Cooper, who, in his description of the accident called by him "partial luxation of the shoulder joint, forwards and inwards, to the coracoid process," gives a case which he supposed to be one of this accident, and relates the symptoms to teach us how it may be recognised; but for its anatomical characters he refers to an example found in the dissecting room, the history of which was unknown. He says, "The only *dissection* of this accident which I have had an opportunity of seeing was the following, for which I am indebted to Mr. Patey, surgeon in Dorset Street, *who had the subject brought to him for dissection* at the anatomical room, St. Thomas's Hospital. The following is Mr. Patey's account : —

"'*Partial dislocation of the head of the os humerus.*— The head of the os humeri on the left side was placed more *forward* than is natural, and the arm could be drawn no farther from the side than the half way to an horizontal position.

"'*Dissection.*—The tendons of those muscles which are connected with the joint were not torn, and the capsular ligament was found attached to the *coracoid process* of the scapula. When the ligament was opened it was found that the head of the os humeri was situated under the coracoid process, which formed the upper part of the new glenoid cavity; the head of the bone appeared to be thrown on the anterior part of the neck of the scapula, which was hollowed, and formed the lower portion of the glenoid cavity. The natural rounded form of the head of the bone was much altered, it having become irregularly oviform, with its long axis from *above downwards:* a small portion of the original glenoid cavity remained, but this was rendered irregular on its surface by the deposition of cartilage. There were also many *particles* of cartilaginous matter upon the head of the os humeri, and upon the hollow of the new

cavity in the cervix scapulæ, which received the head of the bone. At the upper and back part of the joint there was a large *piece of the cartilage which hung loosely into the cavity*, being connected with the synovial membrane at the upper part only by two or *three small membranous bands*. The *long head of the biceps* muscle seemed to have been *ruptured* near to its *origin* at the upper part of the glenoid cavity, for at this part the tendon was very small, and had the appearance of being a new formation.' — Signed, James Patey.

"This accident," adds Sir Astley, "happens from the same cause which produced the dislocation forward. The anterior part of the ligament is torn, and the head of the bone has an opportunity of escaping forwards to the coracoid process." *

The foregoing dissection, which is illustrated by an engraving in Sir A. Cooper's work on Fractures and Dislocations, should not, in our opinion, be considered in any other light than as an excellent specimen of the anatomical appearances to be found in those who have had chronic rheumatic arthritis of the shoulder joint; for we consider that these appearances were not the result of an accidental luxation, but the true effects of this slow chronic disease. If Sir A. Cooper had known any thing of the history of the case during life, we might hesitate to call in question the opinion of so eminent an authority on such a subject; but as the only grounds he possessed for forming any opinion were derived from the mere anatomical appearances observed in the shoulder joint of the subject in the dissecting-room, we conceive that every one who studies the report of this dissection, accompanied as it is by an engraving, is at liberty to draw his own conclusion as to what was the real nature of the case; and to us it seems quite clear that the appearances observed in the examination of the case referred to by Sir A. Cooper were exactly those most frequently found to be the result of chronic rheumatic arthritis as it affects the shoulder joint. The new form assumed by the head of the humerus, the fact of the cartilage having been removed, and its place supplied by an ivory enamel — the piece of cartilage which hung loosely into the cavity being connected with the synovial membrane, at the upper part only, by two or three small *membranous bands* — the attachment of the capsular ligament to the coracoid process — all these circumstances related in the above-mentioned case strongly remind us of what we now know to be characteristic marks of the disease we have denominated chronic rheumatic arthritis, as we have so often met with them. Add to this, the observation that the intra-articular portion of the long tendon of the biceps muscle did not exist; or, as is presumed, to have been "ruptured" at its origin. In all these details we find a very complete account of the anatomy of the shoulder joint which had been the seat of chronic rheumatic arthritis.

On the other hand, such appearances afford no evidence whatever that an accidental luxation was the cause of them; certain it is that appearances exactly resembling those described in Sir A. Cooper's case have been met with in cases in which their cause could not be attributed to accident, because no injury had been received; while in others it was useless to refer to accident, inasmuch as the morbid action had similarly affected *both shoulder joints;* so that by the dissection of such cases we have convinced ourselves *that disease, not accident*, was the source of the morbid appearances. If the reader will compare the woodcut (*fig.* 429.), which is designed to represent the anatomical appearances presented by the examination of a case (J. Byrne) already detailed, of chronic rheumatic arthritis of the shoulder, with the engraving of Sir A. Cooper's case of partial luxation of the head of the humerus, he will, we think, agree with us that the writer, in believing that whatever causes influenced the production of the morbid appearances in the one were identical with those which produced them in the other. Sir A. Cooper, in our opinion, somewhat *gratuitously* supposes that his specimen was the much sought-for example of the anatomy of the accident called partial luxation. We say *gratuitously*, because the previous history of the case he alludes to was unknown, and the accident *supposed* to have occurred.

In the case the writer has adduced (J. Byrne, (*fig.* 429.), the history was known, and has been preserved, with the account of the post-mortem appearances which the examination of the shoulder joint presented.

At the meeting of the British Association at Bristol in September, 1836, the author gave an account of this chronic rheumatic disease, as it engages most of the joints. When speaking of its effects on the shoulder, he alluded to this case published by Sir A. Cooper; and then demonstrated, as he thought, to the satisfaction of the meeting, that the specimen (*fig.* 429.) of this chronic rheumatic disease which he then laid before them for inspection, corresponded exactly to the appearances found in the supposed case of "partial luxation of the humerus" delineated in Sir A. Cooper's work. The opinion which he at that time expressed (now twelve years ago) has since been amply confirmed by his subsequent experience *, and by the opportunities he has had of further investigating the nature of this disease.

In the *Museum Anatomicum* † of Sandifort, 1827, we find delineated the bones of the shoulder joint which present all the cha-

* See Sir A. Cooper on "Dislocations," p. 449. Plate 21. fig. 2.; also octavo edition of this work by Mr. B. Cooper, p. 401.

* See Athenæum, September 10, 1836; also Proceedings of the Dublin Pathological Society, Dublin Journal, vol. xv. p. 502.

† Vol. iv. tab. 24. *figs.* 1, 2, 3.

racters of the chronic rheumatic arthritis, with partial displacement upwards of the head of the humerus. Sandifort also, we feel sure, has fallen into the error of concluding without proof, that this specimen of the bones of the shoulder constituted an example of partial luxation *from accident* ("luxatio ossis humeri ab *injuriâ externa*"). The subject of this case, he says, was a robust man: the head of the humerus having been driven upwards between the coracoid process and the acromion, a new articular surface was produced, partly on the upper narrow part of the glenoid cavity, and partly on the root of the coracoid process. This new articular surface, in its centre porous, was as to its circumference hard, polished, and ivory-like ("partim porosa sed cætera valdè polita ac quasi eburnea"), and had been in habitual contact with the head of the humerus. The latter was much enlarged, and its circumference near the corona of the head was much increased by the addition of a hard rounded margin ("margine revoluto calloso"). The wearing away of the upper part of the great tuberosity, the eburnisation of the summit of the humerus where it came in contact with the concavity of the coraco-acromial vault, the preternatural contact of the head of the humerus with the under surface of the acromial extremity of the clavicle, are also noticed. "Caput ossis humeri amplitudine auctum, margine revoluto calloso, in superficie articulari affert eandem præternaturalem glabritiem et duritiem, dum in vertici, ubi tuberculum majus occurrit, superficiem exhibet partim glaberrimam, partim inequabilem, rugosam, quæ juxta summum humerum movebatur trituratione, etiam locum habuisse inter marginem inferiorem claviculæ, et verticem capitis humeri manifeste apparet; subluxatio in superiora ergo hic locum habuit."*

Here we find the description of the bones unaccompanied with any account of anatomical characters of the other structures of the joints; nor is there any proof adduced that any accident had occurred to produce the appearance noticed; we may therefore, we think, conclude, that the history of the case was unknown. When we compare Sandifort's description of the above case, accompanied as it is with an engraving, with the account given by us in the preceding pages of the dissection of other cases of the chronic rheumatic arthritis as it affects the structures of the shoulder joint, we think we may safely conclude that this case, adduced by Sandifort as an example of partial luxation of the head of the humerus upwards from external injury, must be considered as presenting in the bones described the anatomical characters of chronic rheumatic disease, as it very commonly affects the bone of the shoulder joint.

In the anatomical examination of advanced cases of this disease of the shoulder joint, which we have witnessed, in which there had been *partial luxation* of the head of the humerus upwards — when the deltoid muscle has been cut through, the head of the humerus has been usually found exposed, and in absolute contact with the under surface of this muscle, having passed through the upper part of the capsular ligament. In such cases, the head of the humerus has been found to present the usual characteristic appearances of this chronic rheumatic disease; that is to say, the cartilage has been absorbed, and its place supplied by an ivory-like enamel. The articular portion of the tendon of the biceps has also been removed, as well as all those parts which in the normal state intervene between the summit of the head of the humerus and the under surface of the coraco-acromial arch. The superior portion of the capsular ligament itself has been found perforated; and the under surface of the coraco-acromial vault excavated, and has become a new and supplementary socket for the head of the humerus (*fig.* 429.).

The explanation of the circumstance why the superior and external part of the capsular ligament has been found perforated by a large circular opening, through which the head of the humerus can pass, appears to be, that the effects of the loss of the tendon of the biceps are such, that the head of the humerus is at once elevated by the deltoid, and kept habitually pressed up against the under surface of the acromion. The coraco-acromial vault now becomes the articular socket for the head of the humerus, more than the original glenoid cavity. The head of the humerus assumes altogether a new form; its summit is expanded, and at the same time smoothed by the constant effects of use and friction; the anatomical neck is encroached upon, and gradually the whole summit, including the great and lesser tuberosities, becomes articular, these latter eminences being, as it were, ground down and covered with a porcelainous deposit (*fig.* 428.). As the upper portion of the circular groove, called the anatomical neck of the humerus, which normally gives attachment to the capsular ligament of the joint, has been removed, this attachment of the capsule must be destroyed, and a large opening will be found in it. This occurrence is well illustrated by a case of chronic rheumatic arthritis of the shoulder joint, described by Mr. Hamilton Labatt, who entitles the case, "An excellent specimen of that chronic disease of the shoulder joint which old people are liable to; as also an example of partial luxation upwards, the result of slow disease."*

The history of this case, as of almost all of the same kind published, was unknown. The subject was a female aged 60, brought into the College of Surgeons for dissection; the muscular system well developed. The common integuments had been removed when Mr. Labatt was called to witness the dissec-

* Museum Anatomicum Sandifort, tab. cli. *figs.* 1, 2, 3. vol. iv.

* Vide London Medical Gazette, 1838, vol. xxii. p. 22.; also Catalogue, Coll. Surgeons, Ireland, vol. ii. p. 396.

tion, and the deltoid muscle was cut across and thrown back, when the attention of the dissector was attracted by the head of the humerus, which was exposed and firmly supported against the under surface of the acromion process by the lips of a vertical rent in the capsular ligament, which was otherwise healthy, firmly girding the anatomical neck of the humerus. The articular cartilage of the head of the humerus had been universally eroded. The head of the humerus had been increased in size by the addition of an osseous margin, which overhung the anatomical neck of the humerus. Several cartilaginous bodies, connected to the surrounding fibrous tissues, projected into the cavity of the joint. The larger were pedunculated and pendulous, while the smaller were attached by broad surfaces. The articular part of the biceps tendon had disappeared. The capsular ligament was thickened; and the longitudinal aperture already mentioned, which existed in the upper part, was sufficiently capacious to allow the head of the bone under certain circumstances to pass with facility from its natural situation upwards, and to come in contact with the under surface of the acromion process. The coraco-acromial articulation of the same side, as well as several of the other articulations in this subject, exhibited unquestionable traces of having been affected with the same disease.*

When a specimen of chronic rheumatic arthritis of the shoulder joint, such as the preceding, has been met with, by anatomists not familiar with the ordinary anatomical characters of the disease, it is usually mistaken for a case of partial displacement of the humerus upwards, the result of accident. We find many such cases and such mistakes recorded. Although the history of Mr. Labatt's case was unknown, the appearances which the head of the humerus presented were sufficiently characteristic to clearly designate the true nature of the affection, independently of the condition alluded to of the coraco-clavicular and other articulations, so many concurring circumstances sufficiently proved that, in the above case, the shoulder had been long affected by the chronic rheumatic arthritis, and that this, and not accident, was the source of the partial luxation upwards which existed.

In April, 1840, Dr. Robert Smith, who is well acquainted with this disease, laid before the Surgical Society of Dublin an account of the post-mortem examination he had made of an aged female, who died of an internal organic disease in the House of Industry. She had been long affected with a partial displacement upwards of the right humerus, which was the result of chronic rheumatic disease. He presented a cast of the upper part of the body, taken after death, showing the degree of elevation of the summit of the humerus on the affected side; and also exhibited a preparation of the shoulder joint to the meeting. The post-mortem examination had been made a few weeks previously to Dr. Smith's communication of this case to the society. "It may be seen," he said, "from the cast, that in this case there was a remarkable contrast in the appearance the two shoulder joints presented: on one side, the head of the humerus was placed far above the level of the coracoid and acromion processes. Many persons," he added, "in viewing the cast and accompanying preparation, might consider the specimen as one of some unusual form of congenital malformation, or the result of accident; but the abnormal appearances were clearly the result of that peculiar affection of the joints, of which so many specimens had been elsewhere brought forward by the president in the chair (Mr. Adams), and which disease he has denominated 'chronic rheumatic arthritis.'" Dr. Smith added that his chief reason in bringing forward the case was, that it presented some peculiarities he had not observed in other specimens of the same disease, as it affects the shoulder joint: he had often before noticed the elevation of the head of the bone as a symptom of this affection, but had never seen the elevation to the same degree it had amounted to in this case. The head of the humerus was displaced upwards, even to a point above the level of the clavicle and acromion process. The capsular ligament was enlarged, and as thin as if the synovial membrane alone constituted it. Superiorly, this capsule was altogether deficient: a large aperture was here found, which permitted the head of the humerus to pass upwards, as already mentioned; the tendon of the biceps was perfect, but was thrown off the head of the bone inwards. The cartilage of the head of the bone was abraded in several places, and osseous depositions had been formed in the vicinity of the bicipital groove, and around the margin of the articular head of the humerus, as is usually the case in examples of chronic rheumatic disease. Mr. Smith observed, that the preparation showed a large deficiency in the upper part of the capsular ligament — a fact not before observed by him, until he had seen Mr. Labatt's preparation; and even then he was disposed to attribute the deficiency to some injury received in removing the parts. He had therefore taken the greatest care in removing the preparation just exhibited to the society, and had found that in dividing the deltoid muscle he had cut at once into the cavity of the joint.

Dr. Smith and the writer have lately carefully examined this preparation, and find that the acromion process has been much reduced in thickness; its under surface is excavated, and denuded of all periosteal covering; this process is divided into two portions, as if a fracture had traversed the original line of the junction of the epiphysis with the rest of the process: half an inch in extent of the bone is thus separated from the rest, and seems merely retained by a ligamentous connection.

The deltoid and triangular ligament were

* This specimen is preserved in the Museum of the College of Surgeons. Vide Catalogue, Coll. Surg. Ireland, vol. ii. p. 396.

relaxed: —"The shoulder joint presented a remarkable degree of mobility in this case; and the head of the humerus of the affected side could be pushed half an inch higher than its fellow." The great peculiarity in this case Dr. R. Smith thought consisted in the circumstance that the tendon of the biceps was not, as it usually is in cases of this chronic disease, absorbed, but was in a perfect state of integrity as to structure.

This tendon having been thrown off the head of the humerus, and displaced inwardly, its normal function to restrain the ascent of the humerus, through the medium of its muscular connection, was as much annulled as if it had been removed altogether, as it usually is, under the influences of this chronic disease.

Questions here naturally arise: Can the tendon of the biceps be dislocated from its groove by accidental violence? and if so, Shall the consequent dislocation of the head of the humerus be in the direction upwards, exactly as it was in the preceding case, which was evidently an example of the displacement of the tendon from disease.

Mr. John Soden, junior, of Bath, has published a case, accompanied by some interesting remarks, the objects of which are to prove that the tendon of the biceps may be dislocated by *accident*, and that a partial displacement of the head of the humerus upwards must immediately follow.

Mr. John Soden's case. — Partial dislocation upwards. — "Joseph Cooper, aged 59, was admitted into the Bath United Hospital, November 9, 1839, on account of a compound fracture of the skull. His death afforded an opportunity of examining an old injury of the right shoulder, the symptoms of which had been always involved in great obscurity, and which occurred in the following manner: —

"In the month of May, 1839, the deceased (six months before his death) was engaged in nailing down a carpet, when, on rising suddenly from his occupation, his foot slipped, and he fell backwards on the floor. In order to break the force of the fall, he involuntarily placed his arm behind him, and by so doing received the whole weight of the body upon his right elbow; that joint, the only one struck, received no injury, for the shock was instantly transmitted to the shoulder, and there the whole effects of the accident were sustained. Acute pain was immediately experienced, and the man supposed he had either suffered a fracture or a dislocation, but finding that he *could raise the arm over his head*, he felt reassured, and endeavoured to resume his work. The pain, however, compelled him to desist, and he went home." "When I saw him," says Mr. Soden, "on the following morning, the joint was greatly swollen, tender to the touch, and painful on very slight motion. There was then no possibility of his placing his arm over his head, as he had done immediately after the accident. I satisfied myself that there was neither fracture nor dislocation of the bones, and not suspecting the existence of a more specific injury than a severe sprain, I set down the case as such, and avoided the unnecessary pain of further examination. Unusually active means were necessary to subdue the inflammation, and at the end of three weeks, though the swelling was much reduced, the tenderness in the front of the joint, and pain on certain motions of the limb, were scarcely less than on the day after the occurrence of the accident.

"On comparing the joint with its fellow, now that the swelling had subsided, a marked difference was observable between their respective outlines. The injured shoulder was evidently out of drawing, but without presenting any glaring deformity: when the man stood erect with his arms dependent, the distinction was very manifest, but difficult to define. There was a slight flattening on the outer and posterior part of the joint, and the head of the bone looked as it were drawn up higher in the glenoid cavity than it should be. Examination verified the appearance in two ways: first, on moving the limb, with one hand placed on the shoulder, a crepitating sensation was experienced under the fingers, simulating a fracture, but in reality caused by the friction of the head of the humerus against the under surface of the acromion: secondly, on attempting abduction, it was found that the arm could not be raised beyond a very acute angle with the body, from the upper edge of the greater tubercle coming in contact with that of the acromion, and thus forming an obstacle to all further progress. The head of the bone was also unduly prominent in front, almost to the amount of a partial dislocation. For all useful purposes the arm was powerless. The pain caused by the action of the biceps was acute, extending through the whole course of the muscle, but felt chiefly at its extremities. When the joint was at rest the pain was referred to the space in front, between the coracoid process and head of the humerus; which spot was marked by extreme tenderness and some puffy swelling.

"The patient being *of a rheumatic habit*, inflammatory aetion of that character was soon established in the joint, so that the peculiar symptoms of the injury were marked by those of general articular inflammation, which added greatly to the man's suffering, and to the difficulty of diagnosis. On examining the joint the accident was found to have been a dislocation of the long head of the biceps from its groove, unaccompanied by any other injury. The tendon was entire, and lay enclosed in its sheath, on the lesser tubercle of the humerus; the capsule was but slightly *ruptured;* the joint exhibited extensive traces of inflammation; the synovial membrane was vascular and coated with lymph; recent adhesions were stretched between different parts of its surface, and ulceration had commenced on the cartilage covering the humerus, where it came in contact with the under surface of the acromion; the capsule was thickened and ad-

herent, and in time, probably, anchylosis might have taken place."

Observations on this case. — In this interesting case, recorded by Mr. Soden, it is true that the tendon of the biceps was dislocated; but, we may ask, are the appearances noticed during life, as well as the condition of the shoulder joint found on examination after death, capable of any other explanation than that given to them by Mr. Soden? Upon such a matter we feel we ought to speak with the greatest diffidence, because this case is so far unlike almost every case of partial luxation yet published in this circumstance, that its history was known before the *post-mortem* examination of the joint was instituted. However, we must confess that we do not as yet feel convinced that the case of partial displacement upwards of the head of the humerus, as the immediate and direct result of accident, has been fully proved by Mr. Soden. If we analyse the symptoms the patient himself reports to have observed immediately after the accident, we find that he at first supposed he had either suffered a fracture or a dislocation, but finding that "*he could raise the arm over his head*," he felt re-assured, and endeavoured to resume his work. It would appear to us, that if the tendon of the biceps were accidentally dislocated the patient would not be able, immediately after the accident, to raise his arm over his head; while the circumstance here noticed seems quite reconcilable with Mr. Soden's own impression, that there was in this instance no other injury than a severe sprain of the joint. The symptoms under which the patient subsequently laboured were those of an inflammatory character, such as might have been expected where so severe a sprain had occurred, as we may suppose the shoulder joint in this instance to have suffered. The appearance the joint presented externally when the disease became subacute, or chronic, namely the flattening of the outer and posterior part of the joint, and the appearance of the head of the bone, which had been drawn up higher in the glenoid cavity, the *crepitating* sensation caused by the friction of the head of the humerus against the under surface of the acromion, the pain felt in the whole course of the biceps muscle, the difficulty experienced in abduction of the elbow from the side, the prominency of the head of the bone in front, almost to "the amount of a partial dislocation,"—all these symptoms we have repeatedly noticed to belong to the affection of the shoulder joint which we have called *chronic rheumatic arthritis*, and all these have been present in patients who have had this disease in both shoulder joints at the same time, and in whom they could not by any means be referred to accident. Finally, before we leave our analysis of the symptoms of this case, we must not omit to allude to the author's own observation—"The patient being of a *rheumatic habit*, inflammatory action of that character was soon established in the joint, so that the peculiar symptoms of the injury were masked by those of general articular inflammation, which added greatly to the man's suffering, and to the difficulty of diagnosis."

The patient being, as we are told, of a rheumatic habit, or predisposed to this articular disease, it may be readily conceived that any injury this man, aged fifty-nine, might receive in the shoulder joint would be well calculated to give rise to the disease which we have called chronic rheumatic arthritis.

As to the anatomical examination of the joint, it will be recollected that the disease had been only six months established, and therefore that the more striking results of chronic rheumatic disease should be found was not to be expected. Those which were noticed, however, were such as might be supposed to represent the anatomical characters of chronic rheumatic arthritis of the shoulder in an early stage.

As to whether Mr. Soden's interpretation of his own case be the correct one, or the doubt we have ventured to express should be considered to have a just foundation, we must leave to the judgment of others, to time, and to the result of future investigations to determine; but the subject must be confessed to be one of a truly practical nature, and therefore worthy of further inquiry.

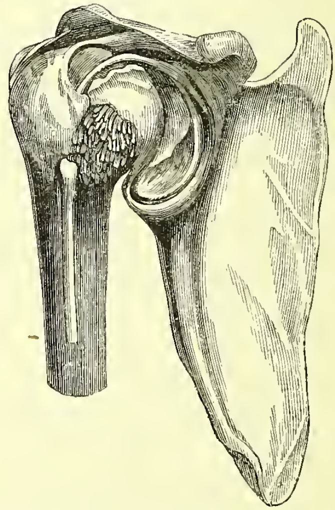
We had written thus much on the subject of partial dislocation of the head of the humerus *upwards*, with displacement inwards of the long tendon of the biceps, when (on the 12th of August, 1848) an opportunity occurred to us of examining anatomically both shoulder joints of a patient who had died in the North Union Poor House the day before, who had been for eight years one of the severest sufferers the writer had ever known from chronic rheumatic arthritis in almost all his joints. The disease existed in an aggravated form in his hips and knees, wrists and elbows, and of late years began also to affect equally both shoulder joints. It was very remarkable that, on examining anatomically the shoulder joints in this case, we discovered the same displacement of the head of the humerus upwards, with dislocation of the tendon of the biceps inwards, as in Mr. Soden's case, in *both* shoulder joints, and with the dislocation of the long tendon in both shoulder joints in this case, which we shall now relate, were found associated the ordinary anatomical characters of chronic rheumatic arthritis in rather an early stage of the disease; while in the other articulations of this same individual the chronic rheumatic disease was in a very advanced state.

Case. Charles Mailly, ætat. 48, had been a farming servant in the country, and was remarkable for his strength and activity. He was addicted to drinking ardent spirits to excess, and it was stated of him that he frequently lay whole nights in the open air in a state of insensibility from drunkenness. To these circumstances he attributed the origin of his disease, which disabled him from earning his bread; he was therefore admitted into the poor house, in 1840. For the last five years he

has been altogether confined to his bed, as he could not stand upright, much less walk, when the writer visited him in August, 1847. His hips, knees, and elbow joints were semiflexed and rigid, his wrist extended, his fingers and toes presented the ordinary characteristic distortion belonging to rheumatic gout, or chronic rheumatic arthritis.* Although the shoulder joints in this case had lost much of their muscular covering, the deltoid and capsular muscles being in a state of atrophy, yet the bones of the articulation seemed much enlarged, and the heads of both humeri were evidently situated much above the level of the coracoid process. He did not complain of much pain in the shoulders; the constant torture he endured in the right hip and both his knees quite distracted his attention from all minor suffering. He stated that he had a "crackling" sensation in all his joints whenever they were moved; that his sufferings were influenced by the weather, and that he endured more pain during the frost of winter than at any other time. The patient died worn out by pain and irritative fever, attended with severe diarrhœa.

Post-mortem examination. — Dr. R. Smith assisted the writer in this examination. As the body lay on its back on the table, the hips, the elbows, and knee joints were semiflexed, and could not be extended, but they permitted of flexing to a very trivial degree. When any of the affected joints were moved, the characteristic crepitus, or crackling, so often alluded to, was elicited now as during life. The head of the os humeri of each side was drawn up much above the level of the coracoid process, and was preternaturally advanced. Upon rotating the humerus, a marked crepitus was evident in these as well as all the other joints. On removing the integument over the right shoulder joint, the deltoid muscle was found pale, and forming a thin attenuated layer of muscular fibres covering the articulation. When this was removed, the sub-deltoid bursa was seen to be of a yellowish colour, and it had a fibrous appearance externally, like to a capsular ligament. When this bursa was freely cut into by an incision parallel to the margin of the acromion, its cavity was observed to be more capacious than usual. The posterior or inferior wall of the bursa was found to have identified itself with the external and superior part of the fibrous capsule of this articulation, and both seemed here to have become degenerated into thin cellular structure, which adhered to and formed a periosteal covering for the summit of the humerus near to the upper part of the great tuberosity. The capsular ligament was elsewhere somewhat thicker than natural, particularly at the upper and anterior part, where it seemed to have identified itself at its origin with the coraco-humeral ligament, which was much thickened. As to its attachment to the humerus, the capsular ligament, superiorly and posteriorly, was very short, having become adherent to the head of the bone before this capsule had reached its usual point of insertion into the anatomical neck of the humerus. Anteriorly and inferiorly the capsule descended on the neck of the humerus *below* its normal level (*fig.* 430.). When this ligament was cut into and examined posteriorly, several broad patches of adhesion were found to exist (as in Mr. Soden's case) between its internal surface and the head of the bone posteriorly, so that in these parts the synovial cavity was completely obliterated by the adhesion of the opposed surfaces of the membrane which lined the capsular ligament, and invested the posterior part of the head of the humerus, just as we find occasionally the pericardium partially adherent to the surface of the heart. When the capsular ligament was fully opened anteriorly, where it is covered by the tendon of the subscapularis, it was seen, more evidently than it could have been previously, that the head of the humerus had been placed habitually above the level of the coracoid process and the highest point of the glenoid cavity from which the long tendon of the biceps springs (*fig.* 430.). The tendon of the biceps lay entirely to the

Fig. 430.



Case of Charles Mailly.— Chronic rheumatic arthritis. The long tendon of the biceps dislocated inwards, the head of the humerus partially displaced upwards, as in Mr. Soden's case.

inside of the head of the humerus; indeed, such was its position, that it might rather be said that the humerus was displaced outwards, and elevated above the level of the course of the tendon of the biceps, than that the latter was dislocated inwards. A semicircular groove marked the course of the tendon of this muscle as it arched across from the highest point of the glenoid cavity to the summit of the bicipital groove. The portion of the head of the humerus which was situated

* See Hand, Vol. II. p. 518. fig. 233.

above the course of the tendon of the biceps was divested of all cartilaginous covering, was of a yellowish colour, and remarkably hard, and presented an appearance as if the summit of the humerus had been prepared for the polish of eburnisation, but as yet no ivory-like enamel had formed, because as yet bone had not come in contact with bone.

The head of the humerus was much enlarged and altered from its normal figure, particularly above, in the neighbourhood of the great tuberosity, which bulged out much externally; the usual deep groove above, separating the tuberosity from the head, and here marking the anatomical neck of the humerus, was effaced.

The under surface of the neck of the humerus was furnished with a vast number of the synovial fimbriæ before noticed by us when describing the anatomical characters of chronic rheumatic arthritis of the shoulder and other articulations. * These were in the recent state of a very red colour. The humerus seemed habitually to have remained in contact with the glenoid cavity, rotated inwards, and in this position these synovial fimbriæ lay in contact with the inferior and broadest part of the glenoid cavity; and it was very remarkable that wherever these red synovial fimbriæ had been in exact apposition with the cartilage of incrustation of the glenoid cavity, exactly in the extent of the contact the cartilage had been removed, satisfactorily proving that these vascular fimbriæ had been absorbing villous surfaces.

The glenoid articular surface presented but little worthy of notice, except a porous appearance where its cartilaginous investment had been removed by the absorbing villi, and the commencing state of disintegration of the glenoid ligament. The cartilage which remained on a portion of the head of the humerus, as well as that which still adhered to the surface of the glenoid cavity of the scapula, was rough, and altered from its natural state. The acromio-clavicular articulation of this side seemed enlarged externally, the periosteum about it thickened. When the articular surfaces were exposed, it was found that the cartilaginous covering had been removed, and that the articular surfaces were nearly double their normal size.

It is quite plain that the movements of the head of the humerus in the glenoid cavity in this case had been confined to those of a species of semi-rotation only; the adhesions which were found to exist between the head of the humerus and the inner surface of the synovial membrane of the joint sufficiently suggest this, as well as the new form which the head of the humerus had assumed.

The left shoulder joint in almost every respect was symmetrically affected with the right, but particularly as regarded the dislocation of the tendon of the biceps, the existence of fimbriæ, &c. &c., and therefore it does not require a separate description.

* See Dublin Journal, vol. xv. p. 159.

It does not appear to us necessary to enter into any details here, relative to the condition the other articulations were found in. The lungs and other viscera were sound. Whether the patient ever had rheumatic fever or not we are not now able to learn; but we may mention that upon looking to the state of the heart and its membranous coverings we found the pericardium adherent to the heart on all its surfaces except where it lay on the diaphragm. It seems to us plain that hereafter, when the tendon of the biceps shall be found displaced internally, we are not at once to refer the dislocation to accident, but that inquiry must be made as to whether chronic rheumatic arthritis may not have been its cause. That the tendon of the biceps should, under the influence of changes which the structures of the joint may have undergone from disease, be thus thrown off the head of the humerus over which it arches, does not appear to us extraordinary, because we have known similar displacement of tendons under analogous circumstances; indeed, we have generally found the extensor tendons of the fingers displaced, and the ligament of the patella and patella itself are sometimes thrown on the outer side of the external condyle of the femur when the knee joint has been the seat of chronic rheumatic arthritis.

In Mr. Soden's case accident may have had just so much to do with the displacement of the tendon, that the injury was the immediate exciting cause of the development of a local disease, a predisposition to which had previously existed in the constitution of the patient.

The writer regrets much that he has not as yet had any opportunity of examining the preparation of the shoulder joint presented by Mr. Soden to the museum of King's College, London; but he requested his friend Dr. Macdowell, at the time in London, and who was familiar with the many preparations of chronic rheumatic arthritis contained in the Richmond Hospital Museum, to report to him his opinion on the appearances the preparation presented, and he writes to say, "that from the partial examination he could make of the preparation he had only to remark, that the head of the humerus is considerably enlarged, and that the long tendon of the biceps, which has been dislocated internally, is in a state of atrophy." In these two additional circumstances, as well as those already mentioned, the preparation resembles those of the shoulder joints in the case of Mailly.

Although we have as yet said but little of any displacement of the head of the humerus occurring as a consequence of this chronic rheumatic disease, except in the direction upwards, and upwards and inwards, yet we would now call attention to facts to prove that the head of the humerus, under the influence of the changes induced by this disease in the structures of the shoulder joint, may suffer a partial displacement directly inwards under the coracoid process;

partially downwards, enlarging the axillary margin of the scapula, so as to form a new glenoid cavity; and lastly, that the infra-spinatus fossa of the dorsum of the scapula may become the new situation, to which the head of the humerus may be transferred from the effects of chronic rheumatic arthritis of the shoulder.

The writer has after much investigation seen but two examples of this last displacement, and, curious to observe, these were in the right and left shoulder joint of the same individual.

Partial dislocation of the head of the humerus inwards. — In the museum of the College of Surgeons, Dublin, we find a specimen presented by Professor Hargrave, which he considers one of *partial luxation* inwards *from accident*. The accidental origin of the affection, however, cannot be proved, as the history of the case is unknown; and the specimen presents so many of the features of the chronic rheumatic disease combined with the partial luxation, that we are of opinion that Professor Hargrave's specimen cannot be considered the result of accident; but that all the appearances it presents are the consequence of long established chronic rheumatic arthritis. We shall here give an abstract of Dr. Hargrave's case, referring for a fuller account to the Edinburgh Medical Journal.

The capsular ligament presented a perfect state of integrity along the superior and posterior part of the joint. It was very dense and strong, extending from the acromion process downwards and forwards towards the humerus. When the capsule was opened on its internal aspect, the head of the humerus was seen to be in part external to the joint, and was divided into two unequal portions by a deep groove extending for the entire length of its head in a perpendicular direction. Of these two portions the internal and larger one passed a small distance beyond the corresponding edge of the glenoid cavity into the subscapular fossa, while the posterior and smaller one remained in the glenoid cavity, occupying its internal surface.

The groove now mentioned fitted on the inner edge of the glenoid cavity, which did not present its usual well defined border, but was rounded off, so as to present a thick lip, from the constant pressure and frequent motion of the humerus upon it. The head of the humerus in its superior aspect was in close apposition with the coracoid process, and had altered in a remarkable degree its form, which in place of being beaked and pointed, was much *expanded*, *flattened* and *slightly* hollowed.

When the articulation was first opened, the tendon of the long head of the biceps could *not be seen*; but on more particular examination it was found to have been *ruptured*, the portion connected with the muscle being intimately attached to the bicipital groove of the humerus, while the portion belonging to the glenoid cavity was much diminished in size, and presented a mere rudimental character in the capsular cavity.*

When we carefully observe this specimen, we notice that it presents many of the general anatomical characters of the chronic rheumatic arthritis, these appearances being of course modified, as to the external shape of the surfaces, by the special peculiarity of the partial displacement which had in this case occurred.

The head of the humerus was much enlarged and mis-shapen. It was found that a large portion of the new articular cavity for the head of the humerus lay on the subscapular fossa, but that a portion of the old glenoid cavity remained, and that the head of the humerus, divided into two surfaces, articulated with both the new and old glenoid cavity. The effects of friction during the movements which took place between the bifid head of the humerus and the double articular cavity, which corresponded to it, were such that perfect and complete eburnisation of parts of the contiguous surfaces took place. This last circumstance could not be said to amount to proof, that chronic disease rather than accident had caused the partial luxation. In addition to the ivory-like enamel, we find also that bony vegetations, or granular nodules of new bone, surround the outline of the new articular surface formed for the head of the humerus; and that small foreign bodies, like sesamoid bones, are seen bordering the edge of the articular cavity posteriorly. All these minor circumstances remind us of the anatomical characters we have found in examining cases of chronic rheumatic arthritis of the shoulder. The coracoid process, we are informed, had altered in a remarkable degree its form, which had become expanded, flattened, and slightly hollowed; in a word, it became articular, as we have often before found it to be, as the result of chronic rheumatic arthritis. The glenoid ligament (Professor Hargrave's case) was absent; and the following description, which we may be excused for recopying, may well be applied, we think, to the ordinary condition of the tendon of the biceps in most of the cases of chronic rheumatic arthritis of the shoulder.

"When the articulation was first opened, the long tendon of the biceps could not be seen, but on more particular examination it was found to have been ruptured, the portion connected with the muscle being intimately attached to the bicipital groove of the humerus, while the portion belonging to the glenoid cavity was much diminished in size, and presented a mere rudiment."

We have already made the remark, that when the shoulder joint is the seat of chronic rheumatic arthritis, the neighbouring acromio-clavicular articulation is frequently affected with this same disease. Now, in carefully examining Professor Hargrave's specimen, we shall find that not only do the anatomical characters which belong to chronic rheumatic

* See Catalogue of the Museum of the R. C. of Surgeons, Dublin, vol. ii. p. 397. Edinburgh Medical and Surgical Journal, for October, 1837.

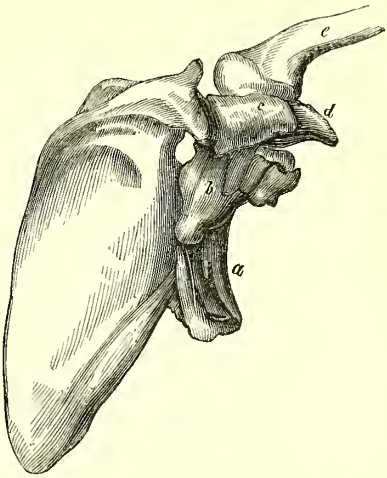
arthritis exist in this shoulder joint, but also that the acromio-clavicular articulation in the same specimen is enlarged externally; and that, on examining it internally, it presents undoubted traces of this chronic rheumatic disease. Upon the whole, therefore, we feel convinced that this specimen produced by Professor Hargrave as an example of a case of partial luxation inwards, the result of accident, does not really afford any proof that external injury was the cause of the partial luxation.

In thus differing from Professor Hargrave, we would make the same remarks which we have already made in allusion to Sir A. Cooper's case, at page 591. of this article. The progress of science will soon settle the question.

Partial displacement of the head of the humerus downwards has been observed to be the result of chronic rheumatic disease of long standing; but after much diligent inquiry in museums and in books, I can find but two well-marked specimens of this morbid change. The most remarkable of these specimens is a left scapulo-humeral articulation, which is contained in the museum of the College of Surgeons, Dublin. The history of the case is unknown: the preparation formed part of the collection presented by Dr. Kirby to the College of Surgeons in Dublin. The head of the left humerus in this specimen is greatly enlarged, and a proportionate glenoid cavity has been formed to receive it. The head of this bone had descended so much beneath its ordinary situation, that a new glenoid cavity had been formed to receive it on the axillary border of the scapula. The lower part of the old glenoid cavity was still partially occupied by the enlarged head of the humerus, but the new addition to the cavity extends downwards for the space of an inch and half below its ordinary situation. The new glenoid cavity is enamelled on its surface, and enlarged on its posterior margin by several irregular-shaped bones of new formation. The capsular ligament in this case has been partly ossified.*

If we look over the engravings in Sandifort's Museum Anatomicum, we shall find, we think, a specimen of partial displacement of the head of the *humerus downwards*, the result of this chronic rheumatic disease. The writer of the catalogue considers the specimen to have been the result of accident, and has appended a history to the case, giving an account of somewhat equivocal symptoms. Whether these symptoms,—such as extensive effusion into the cavity of the joint, of crepitus having been felt on the motions of the bones on each other,—were the result of accident or of disease, their origin is referred to accident. When we carefully compare the engraving with what we have seen of other specimens of this disease elsewhere, we must, we think, come to the conclusion, that this example adduced by Sandifort must be considered as the result of chronic rheumatic

Fig. 431.



*Scapula and portion of the clavicle connected to it, viewed externally.**

a, glenoid cavity; *b*, a fragment of bone apparently of new formation; *c*, anterior part of acromion separated from the spine of the scapula and reunited to it; *d*, extremity of the coracoid process; *e*, clavicle adhering to the acromion broken off from the spine of the scapula. The acromion process was depressed, and "omnem motum claviculæ sequebatur." *(After Sandiford.)*

arthritis of long standing, with partial displacement of the altered head of the *humerus downwards* (*fig.* 431.). Upon looking at the woodcut we notice the acromio-clavicular articulation enlarged as if from chronic rheumatic disease. The acromion process is divided into two portions; a phenomenon we have so frequently noticed to accompany this disease of the shoulder joint (see p. 587.). We also notice the additional portions of bone of new formation attached to the capsular ligament so common in this disease, and the addition of an osseous margin to the glenoid cavity; all these circumstances, so well seen in the original drawing to be found in Sandifort's work as large as nature, we have attempted, in a reduced form, to repeat here.

Finally, the head of the humerus may be not only displaced partially upwards as the result of this chronic rheumatic disease, partially inwards, and, as we have just proved, also partially downwards, but the most remarkable abnormal appearances the writer has witnessed from this chronic disease, has been in two specimens contained in the Museum of St. Bartholomew's Hospital, in which it will be found that the head of the humerus, which had been affected by this chronic disease, was thrown completely backwards on the dorsum of the scapula. In this case the displacement was double, and two new glenoid cavities had

* See Catalogue of the Museum of the College of Surgeons, Dublin, pp. 406—905. &c. See also plate IX. *fig.* 7. of a work on chronic rheumatic arthritis, shortly to be published by the writer; illustrated by lithographic drawings of natural size.

* Diminished drawing from one in Sandifort's Museum Anatomicum, vol. iv. table 25. *fig.* 2.

been formed for the reception of the enlarged heads of the humeri behind the glenoid cavities, and partly beneath the bases of the spines of the scapulæ just where the head of the humerus has been found to rest in the ordinary dislocation backwards from accident; but in this case, although the history was unknown, that these appearances were not the result of accident is almost certain, as similar abnormal appearances are observable on each side. The notice of this preparation in the catalogue of the museum is as follows (p. 108—32.): — " The bones of both the shoulder joints of an adult. In each joint there has been ' ulceration,' or such absorption as occurs in chronic rheumatism of the articular surface of the head of the humerus, and the glenoid cavity. The heads of the humeri are flattened and enlarged by growths of bone *around their borders;* and the glenoid cavities, enlarged in a corresponding degree, and deepened, extend backwards and inwards to the bases of the spines of the scapulæ. The articular surfaces, thus enlarged, are mutually adapted, and are hardened, perforated, and in some parts polished and ivory-like. The changes of structure are symmetrical, except in that the articular surfaces of the right shoulder joint are more extensively polished than those of the left."

Section II. — *Accident.* — The principal accidents the shoulder joint and the bones in its immediate vicinity are liable to, are *fractures* and *luxations.*

Fractures. — A fracture may traverse the acromion, the coracoid process, or detach the glenoid articular portion of the scapula from the body of this bone by passing directly across the neck of the scapula.

A. *Fracture of the acromion process.* — A fracture of the acromion process may be caused by the fall of a heavy body on the superior surface of the acromion; but this accident most usually occurs in consequence of falls in which the patient is thrown from a height on the point of the shoulder. The fracture of the acromion will be generally found to have taken place at a point behind, and within, the junction of the clavicle with this bony process; its direction we always observe to be in the original line of the junction of the epiphysis with the rest of the bone. In this accident, if the distance be measured from the sternal end of the clavicle to the extremity of the shoulder, it will be found lessened on the injured side. Considerable ecchymosis of the shoulder may be expected soon to succeed the injury, and the patient will be unable to elevate the arm. Sometimes the periosteum of the acromion is not torn, and then, although the fracture of the bone has been complete, there is no displacement of the fragments. If, however, this fibrous investment of the acromion, above and below, be completely torn across, the acromion process will be found to be depressed, because it will be pulled down by the weight of the extremity and contraction of the deltoid muscle. The portion of the acromion thus detached is generally very moveable, following the clavicle whenever the arm is moved. This accident is best recognised by the surgeon first taking hold of the elbow of the affected side, and elevating the whole arm perpendicularly. " Having thus restored the figure of the part, he places his hand upon the acromion, and rotates the arm, when a crepitus can be distinctly perceived at the point of the spine of the scapula." *

Fractures of the acromion unite by bone, sometimes with much deformity, arising from ossific depositions, which however do not, after a time, interfere much with the motions of the arm. This union has sometimes been known to take place in forty-eight days, and in other cases in a much shorter time. The union, however, is frequently only ligamentous. Sir A. Cooper speaks of a false joint being occasionally the result of a fracture. Malgaigne, alluding to a case in which a false joint was the consequence of a fracture of the acromion, says that the fractured surfaces presented a polished appearance, and were covered with an ivory deposit, the effects of friction. He adds, that the union was not simply a ligamentous connexion, but that an arthrodial false joint had been formed. In all the specimens of this fracture examined by Malgaigne, the superior border of the fracture was surmounted with small bony crests of new formation, of which the more considerable number grew from the scapular portion of the acromion, while those produced from the detached extremity of this process were but few, no doubt in consequence of its lesser degree of vitality. This remark of Malgaigne coincides with the observations to be found in Sir Astley Cooper's Work, that the disposition to ossific union is very weak in the detached acromion. Malgaigne, however, refers to a preparation in the Museum of Dupuytren, in which the *external* fragment possessed a thickness almost double that of the portion of bone from which it had been detached. This thickness the writer of the Catalogue of the Museum thought was caused by an overlapping of the fragments of the broken portions of the acromion; but Malgaigne supposes it to have arisen from simple hypertrophy of the detached fragments.

B. *Fracture of the coracoid process* — is a rare accident, and when it does occur, it is generally the result of a severe injury, in which the fracture of the bone is the least of the evils attendant on the compound injury. Thus Boyer† gives us the account of a fracture of the coracoid process produced by the blow of a carriage pole; the patient died in a few days afterwards, in consequence of the severe contusion he suffered at the moment of the accident. The coracoid process, when fractured at its basis, is pulled downwards and forwards by the lesser pectoral coraco-brachialis and short portion of the biceps muscle. We are told‡ that if the contusion accompanying this accident be slight, we can seize

* Sir A. Cooper.

† Maladies Chirurgicales.

‡ Sanson.

the fragment between the finger and thumb, and prove at once the mobility of the fragment and the existence of crepitus.

If, says Boyer, the soft parts were in the natural state, we could easily recognise the fracture of the coracoid process, when it has occurred; but so much force is necessary to produce this fracture, that the considerable swelling which always accompanies it, prevents us from being able to recognise the characters of the injury, so that it is not generally ascertained except in the dead body.

C. *Fracture of the neck of the scapula.* — By a fracture of the neck of the scapula is meant a fracture through the narrow part of the bone immediately beneath the notch on the coracoid margin of the scapula, by which the glenoid or articular portion of the bone, together with the coracoid process, becomes detached from the rest of the scapula; the head of the humerus falls into the axilla, with the glenoid cavity attached to it by means of the capsular ligament.

Sir Astley Cooper says the diagnostic marks of this injury are three: first, the facility with which the parts are replaced; secondly, the immediate fall of the head of the bone into the axilla when the extension is removed; and thirdly, the crepitus which is felt at the extremity of the coracoid process when the arm is rotated. The best method for discovering the crepitus is as follows; let the surgeon's hand be placed over the top of the shoulder, and the point of his forefinger be rested on the coracoid process; the arm being then rotated, the crepitus is distinctly perceived, because the coracoid process being attached to the glenoid cavity, and being broken off with it, although itself uninjured, crepitus is communicated through the medium of that process. We believe this accident to be exceedingly rare.

D. *Fracture of the superior extremity of the humerus.* — The superior extremity of the humerus may be broken across, in the line of its anatomical neck, or through the head of the bone above this oblique line. In both cases the fracture will be intra-capsular.

Secondly, the fracture may be extra-capsular, passing through the tubercles; beneath the anatomical neck of the humerus, yet above the line of the junction of the epiphysis, with the shaft of the bone.

Thirdly, a fracture may traverse the humerus in the line of junction of the epiphysis with the shaft of this bone, or close to this line.*

Fourthly, the humerus may be fractured in the part called the surgical neck, beneath the line of junction of the epiphysis with the shaft.

1. *Intracapsular fracture of the humerus.* — We find on record fractures of the head of the humerus, which were altogether intra-articular; and in these cases the head of the bone was separated at the proper anatomical neck. Boyer states he has met with many such cases, most of which were fatal from the severity of the injuries which accompanied the fracture. He mentions the case of a woman who lived for seven days, after having received one of these severe injuries. On making a post-mortem examination of the shoulder, the separated head of the humerus had suffered a great loss of substance; it was hollowed out as to its fractured surface, so as to represent a complete hollow cap or "calotte." It seems to be the opinion of many, that in cases of intra-capsular fractures of the superior extremity of the humerus, unless some portions of synovial membrane and periosteum remain unbroken, no bony consolidation can occur. This may be true as to some fractures; but, on the other hand, we have evidence of cases in which the head of the humerus must have been completely broken, as well as all its membranous coverings severed; and yet perfect reunion of the portion of bone which had been detached was established; but in these cases it is to be observed, that impaction, to a certain degree, of the head of the humerus into the shaft, had occurred.

The possibility of the consolidation, by bony union of a fracture of the anatomical neck of the humerus had been long doubted. Upon this subject, J. Cloquet observes: "I have, some years ago, made known a case of fracture of the humerus through its anatomical neck, which had been perfectly united. Reïchel had before published a similar fact: sometimes the consolidation in these cases would appear to be accomplished by the agency of the inferior fragment, from which spring up stalactiform productions, which surround and encase the superior fragment." He adds, "we have also met with examples, in which consolidation did *not* take place. In these last cases, the head of the bone has been found to have been hollowed out, by contact with the inferior fragment, so that a false joint had been formed in the situation of the fracture; and the superior fragment, by its inferior surface, represented a hollow cup, or 'calotte articulaire.'"*

The following cases will show that a fracture through the anatomical neck of the humerus may occur, in which the head of the bone may be subsequently impacted into the shaft, and be then consolidated by bony union.

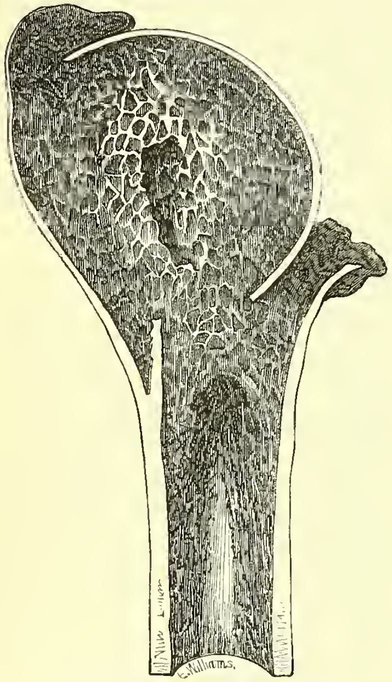
A female, æt. 47, was admitted into the Richmond Hospital, under the care of the late Dr. Macdowell, for an injury of the humerus, the result of a fall upon the shoulder. The case has been merely entered in the Hospital Case-Book, "a fracture of the humerus." Five years afterwards, the woman was admitted into the same hospital, under the care of Mr. Adams, for another injury, a fracture of the thigh, of which she died. *Post mortem*, the shoulder was care-

* Dr. R. Smith has exposed well the error of confounding together as the same the line of the anatomical neck of the humerus, and the line by which the superior epiphysis is united with the shaft of the bone.

* Cloquet, Dictionnaire de Medicine, article FRACTURE.

fully examined. The arm was slightly shortened. The contour of the shoulder was not as full nor as round as that of its fellow, and the acromion process was more prominent than natural. Upon opening the capsular ligament, the head of the humerus was found to have been driven into the cancellated tissue of the shaft, between the tuberosities, so deeply as to be below the level of the summit of the great tubercle ; this process had been split and displaced outwards; it formed an obtuse angle with the outer surface of the shaft of the bone. The distance to which the superior fragments had penetrated into the shaft is well seen in the wood-cut (*fig.* 432.)

Fig. 432.



The head of the humerus impacted.

Nelaton and Smith* have alluded to cases of intra-capsular fractures of the head of the humerus, in which the detached head of the bone became inverted on itself, and was thus impacted into the shaft of the humerus. Nelaton observes : — " Dr. Dubled showed me a specimen, in which the cap which the summit of the head of the humerus forms had been broken from the shaft, and afterwards inverted on itself, so that the broken surface of the upper fragments looked upwards and inwards, while the smooth polished articular part looked downwards, and in this position was buried into the shaft or inferior fragment. Notwithstanding this displacement, consolidation had taken place." The superior fragment was enveloped by stalactiform productions, which had sprung up from the shaft of the humerus.

In the year 1843, Dr. Robert Smith laid before a meeting of the Pathological Society of Dublin, a remarkable specimen of a fracture of the neck of the humerus, in which the head of this bone was driven into the shaft, splitting asunder the bone in the situation of the tuberosities. The subject of the observation was a woman, æt. 40, who, many years before her death, had met with the accident. On proceeding to make the post-mortem examination of this ease, it was remarked that the acromion process was prominent; the deltoid flattened ; the arm was shortened ; the glenoid cavity could not be felt ; the shaft of the humerus was drawn upwards and inwards, so as to be almost in contact with the coracoid process; the motions of the joint were limited ; and the capsular muscles atrophied.

Dissection. — When the soft parts were removed, and the capsular ligament was opened, the traces of a fracture having long ago passed through the anatomical neck of the humerus were obvious. The head of the humerus was solidly united to the shaft. But, upon examining further, what struck Dr. Smith as very remarkable was, that the head of the humerus was found reversed, or turned upside down, in the articulation ; or, in other words, the fractured surface was turned upwards towards the glenoid cavity, and the cartilaginous articulating surface turned downwards, as in Nelaton's case, towards the shaft. The only explanation of this eircumstance which can be given is, that the head of the bone, at the time of the accident, had been completely separated from the shaft by a fracture through the anatomical neck ; that thus rendered free in the interior of the joint, the head of the bone became inverted on itself, and was thus subsequently driven into the cancellated structure, between the tubercles.

It appears that in the Museum of the College of Surgeons of Dublin, a third specimen of this complete inversion of the upper fragment of the broken humerus is to be found.*

2. *Extra-capsular fracture through the tubercles.* — The fracture may be extra-capsular ; passing through the tuberosities *beneath* the anatomical neck of the humerus, yet *above* the line of the junction of the epiphysis, with the shaft of the bone.

This fracture is usually the consequence of severe falls on the outside of the shoulder ; it may occur at all ages, but is most frequently met with in elderly persons. The line of the lesion may be transverse, but usually the bone is broken into many fragments. There is some shortening of the arm, but very little if any transverse displacement of the bony fragments The long tendon of the biceps, in front, and the strong fibres proceeding from the bony attachment of the capsular ligament and capsular muscles, will retain the fragments in their place. The shortening is the result of the mutual impaction into each other of

* Dr. R. Smith's work on Fractures.

* See Dr. R. Smith's work on Fractures.

the superior and inferior fragments. As the fracture thus generally exists without any very obvious displacement of the fragments, and as it is usually accompanied by much swelling of the shoulder joint, the diagnosis may be very obscure.

Symptoms. — The patient will complain of severe pain in the shoulder, which is much increased by the least pressure, or by communicating any movement whatever to the arm; and he cannot, by any voluntary effort of the muscles of the injured arm, elevate it; on making a methodical examination soon after the accident has occurred, crepitus can be elicited. As to the degree of power which the patient possesses of moving his arm in these cases, some variety may be noticed, particularly if some days have elapsed since the receipt of the injury.

The following case of fracture through the tuberosities of the humerus was very recently under observation at the Richmond Hospital, and may be here adduced, to show the difficulty that may occur in making our diagnosis if the case is not seen soon after the occurrence of the accident.

Case. — Mary Trainor, æt. 60, was admitted into one of Mr. Peile's wards in the Richmond Hospital on the 19th of May, 1848. She complained much of the left shoulder, on which she had fallen fourteen days before. She had never used her arm since the accident, nor left it unsupported. The patient pointed to one part close to the head of the humerus anteriorly, which was particularly painful, and here a small bony projection was detected, whether a spicula of bone or a small exostosis could not be known. She could elevate, or abduct her arm some inches from her side, and could *rotate it freely* herself, without these movements causing her any pain. Although many examinations had been made since her admission into the hospital, no satisfactory evidence of crepitus could be detected; there was some tumefaction, and heat showing inflammation of the shoulder joint. She died suddenly of apoplexy on the fourth day after her admission.

Post-mortem. — Before the shoulder joint was examined, it was ascertained by careful measurement from the posterior angle of the acromion to the outer condyle of the humerus, as well as from the scapular extremity of the clavicle to the same point below, that the left or injured arm was fully one quarter of an inch shorter than the right. On removing the muscles and their tendons, a fracture was seen to have traversed the superior extremity of the humerus: the line of this fracture was somewhat irregular; posteriorly it passed along the basis of the head of the humerus, or nearly as high as the level of the anatomical neck, and anteriorly along the basis of the lesser tuberosity, which was thus left attached to the head, while the greater tuberosity was detached, and broken into fragments; and it appeared as if this last was the mechanical result of the impaction of the head into the cancelli of the shaft of the bone; the amount of this impaction was to the extent of one quarter of an inch. The synovial membrane was perforated or punctured in one or two points by spiculæ of the broken humerus, and this membrane showed decided traces of having been the seat of inflammatory action. The cartilaginous covering of the head of the humerus seemed to have been somewhat thinned — the result of the inflammation which had engaged the joint more or less ever since the occurrence of the accident.

The diagnosis in this case was very difficult, for there was some swelling and decided inflammation of the shoulder joint: fourteen days had passed since the accident occurred, and no crepitus, although carefully sought for, could at this period be detected. Apparently self-persuaded that no fracture existed, the woman repeatedly showed to Mr. Robert Macdonnell (the resident pupil, who had immediate charge of the case) how freely she could rotate the injured humerus; she could also abduct the elbow some inches from her side. A fracture through the superior part of the humerus was suspected; but as there was no obvious displacement of the fragments, the principal indication seemed to be to reduce the inflammation of the shoulder joint, and this line of practice was pursued. The expedient of making a comparative measurement as to the relative length of the two arms was not thought necessary as an aid in the diagnosis of this case; yet the result of this experiment would have shown in the living as it did subsequently in the dead body, a decided shortening of the left arm to the amount of a quarter of an inch, an observation which would no doubt have confirmed the idea already existing in the minds of the attendants, that a fracture of the humerus existed, as well as an inflammation of the shoulder joint.

3. *Fracture of the superior extremity of the humerus through the line of junction of the epiphysis with the shaft of the bone, or close to this line.*

This is a species of fracture which not unfrequently occurs in early life. In the old subject we occasionally witness cases of fracture in the same situation. This accident is so far unlike that last adverted to, that while in the former there is no displacement, the latter accident is attended with considerable deformity. We may make this general remark with respect to fractures above the line of junction of the epiphysis, whether the fracture be extra-capsular or intra-capsular. — There is little or no deformity, and crepitus (a symptom of fracture, the possibility of eliciting which usually exists), and shortening to a small amount of the length of the humerus, are the only positive signs to which we can refer to establish our diagnosis; but when a fracture of the humerus, either at the line of junction of the epiphysis with the shaft of the bone, or *below* this line in the surgical neck, occurs, then much displacement of the fragments may generally be observed.

Sir A. Cooper has described an assemblage

of symptoms belonging to a class of cases of fracture of the superior extremity of the humerus, which we have no doubt he conjectured to belong to the separation of the superior epiphysis from the shaft of the humerus in the young subject. In the adult, a fracture through the original line of junction of the superior epiphysis with the shaft of the humerus would be attended with nearly similar symptoms. In alluding to the injury in question, Sir A. C. observes, that in children it is the result of falls upon the shoulder. The signs of it are as follow: — The head of the bone remains in the glenoid cavity of the scapula, so that the shoulder is not sunken as in dislocation; when the shoulder is examined a projection of bone is perceived upon the point of the coracoid process, and when the elbow is raised and brought forward this projection is rendered particularly conspicuous. By drawing down the arm the prominence is removed, but it immediately re-appears upon ceasing to make the extension, and the natural contour of the shoulder is lost.

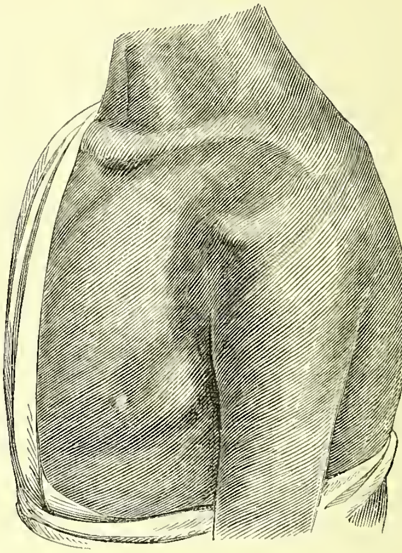
All the movements of the shoulder joint are painful, and the patient cannot raise the arm unless by the aid of the other hand. The elbow is with difficulty withdrawn from the side, and the arm requires support. Sir A. Cooper adduces a case illustrating the above symptoms in a child æt. 10, who had fallen on the shoulder into a sawpit the depth of which was eight feet.

The writer has witnessed many examples of fracture of the humerus in the line of junction of the superior epiphysis with the shaft of the bone, or in the immediate vicinity of this line.

In these cases the youth of the patient, and the situation of the fracture, led him to conjecture that a separation of the superior epiphysis of the humerus had occurred; but he had no opportunity of ascertaining anatomically the true nature of the lesion.

The principal deformity noticed by the writer in these cases is attempted to be delineated in (*fig.* 433.), the representation of one of the plaster casts which he has preserved of one out of many of these cases. The prominence here delineated is found to be owing to a very remarkable projection forwards of the upper extremity of the inferior fragment of the humerus. This was best seen by viewing the shoulder in profile, or sidewise. The antero-posterior measurement of the shoulder was much increased. Sir A. Cooper, in reference to the cases he has seen of this kind, observes, that when the shoulder is examined a projection of bone is perceived "at the front of the coracoid process;" in four cases which the writer has witnessed, the projection of bone formed by the superior extremity of the lower fragment of the humerus was situated exactly in the centre of a line stretching anteriorly from the acromio-clavicular articulation to the lower margin of the anterior fold of the axilla. This remarkable projection of the bone, formed by the lower fragment, was in two cases engaged in the deeper layers of the integuments covering the deltoid muscle near to its anterior margin, and hence the deltoid muscle must have been itself perforated. In these latter cases it was found impossible to disengage the bone from its faulty position, or from the fibres of the deltoid

Fig. 433.



Case of C. Austin. Fracture of the humerus in or near the line of junction of the epiphysis.

muscle, and deeper layer of the integuments. The following case of the above description has been recently seen by the writer.

Case.—Fracture through the humerus immediately below the tuberosities, or through the original line of junction of the epiphysis and shaft of this bone.— Charles Austin, aged 14 years, on the morning of the 12th April, 1848, fell from a height of seven feet off a ladder, and was thrown on the posterior part of his left shoulder on uneven ground. He was not seen until next morning, when the injured shoulder presented the following appearances *: — "There was a great deal of ecchymosis and swelling about the joint; the acromion process appeared prominent, and in viewing the shoulder sidewise the measurement of its antero-posterior diameter appeared greatly increased. The patient supported the hand and fore-arm of the injured arm with the opposite hand; the elbow was slightly abducted, but it could be readily pressed against the side. He could not himself make the least effort to move the arm, and the attempt to raise it from the side, or to deprive it, even for a moment, of the support of the right hand, was productive of much pain. On placing one hand over the joint, and rotating the humerus with the other,

* For the notes of this case, the writer is obliged to Mr. W. Court, resident surgeon to Steeven's Hospital, with whom he examined it.

a distinct crepitus could be perceived. The head of the bone could be felt in the glenoid cavity, and when the shaft of the humerus was rotated no motion was communicated to the head. On the seventh day after the accident all swelling had subsided, and the appearances noted were as follows: — On viewing the shoulder in front, a very remarkable angular projection of bone forwards is observed. This prominence is very near the anterior margin of the deltoid muscle, and near the centre of a line drawn from the scapular end of the clavicle to the margin of the anterior wall of the axilla. This projection is evidently the abrupt termination of the upper extremity of the lower fragment of the humerus; every movement communicated to the shaft of the bone also moves this projecting point, a little below, and to the outside of which, an indentation or slight puckering of the skin is observable. This last we can readily suppose has been produced by the lower fragment having perforated the deltoid muscle, and engaged itself in the deeper layer of the integument.

"On viewing the joint sidewise or in profile, the posterior angle of the acromion projects much behind, while the abrupt prominence already mentioned, formed by the shaft of the humerus, is very salient in front; so that in this side view, the antero-posterior diameter of the joint is seen to be much increased. The long axis of the arm is directed from above downwards and backwards, *very slightly* also outwards. By measurement from the acromion to the external condyle of the humerus, the injured side is found to be a quarter of an inch shorter than the opposite. The patient cannot himself perform any of the movements of the shoulder joint, except that of rotation to a small extent, but can permit the humerus to be freely moved by another. Although crepitus was evident at first, now, seven days having elapsed since the accident, it can no longer be elicited.

"*May* 17*th*. — Nearly a month has passed since he received the fall; he has regained considerable power of motion over the left arm, can even raise his hand to the top of his head. On the 6th of June he left the hospital, being able to use his arm; the deformity, consisting in the abrupt projection of bone, was somewhat reduced."

4. *Fracture of the surgical neck of the humerus* below *the tuberosities and original line of junction of the epiphysis with the shaft of the bone.* — In this case there is much deformity to be observed. The head and tuberosities form the superior fragment, which in general remains in its natural situation, while the upper extremity of the lower fragment, which last is constituted by the principal part of the shaft of the humerus, is drawn upwards and forwards under the pectoral muscle. When the arm is grasped at the elbow by the surgeon, and pushed upwards, the upper extremity of the broken shaft of the humerus is made to project at the inner side of the coracoid process of the scapula, and is felt to roll whenever the arm is rotated.

Fracture of the humerus in its surgical neck occurs at different heights in this bone. The most common situation for the fracture is where the spongy portion of the bone unites with the rest of the shaft; and here it is that the humerus, considered anatomically, would seem to be the least capable of resisting external violence. The direction of the fracture is generally transverse, more rarely is it oblique, and, in this last case, the obliquity is generally in a line from without inwards, and from above downwards, parallel to the line of the anatomical neck of the humerus, but below it, and the nature of the displacement is variable. Most frequently the inferior fragment is drawn inwards towards the axilla; but the inferior fragment has been also observed to be displaced and become prominent in other directions. Desault has seen it thrown backwards; Dupuytren, Paletta, Duret, and others, have seen it raised up, and even perforate the deltoid muscle outwards; finally, it more frequently still has been observed to become prominent in front towards the coracoid process.

Mons. Gely has, in the Journal de Chirurgie, mentioned a case of fracture of the surgical neck of the humerus, in which the fracture was oblique, the obliquity running parallel with, but below, the anatomical neck of the humerus. The inferior fragment had perforated in front the deltoid muscle, very near to the interstice which separates the deltoid from the pectoral muscle; the arm was shortened an inch. These observations refer to the altered position of the inferior fragment, resulting from a fracture through the part of the humerus called the surgical neck. It is said that usually the superior fragment remains in its normal position in these fractures, but this is not always the case. Malgaigne narrates a case of a man, aged 78, in whom the humerus was fractured transversely in its surgical neck, about an inch and a half above the folds of the axilla. There was an overlapping of the bones; the injured arm was consequently one inch and a half shorter than the other. The fracture *during life could not be reduced;* he died on the twenty-sixth day after the injury. The inferior fragment was drawn inwards and forwards, and indeed during life had raised up the soft parts towards the union of the deltoid and pectoral muscles, more internally than the situation of the coracoid process; the overlapping of the fragments was to the amount already mentioned. The fracture through the humerus was beneath the tuberosities, the longitudinal axis of the lower fragment was in the direction upwards and inwards, and the longitudinal axis of the upper fragment was directed downwards and outwards. In a word, the superior fragment was in a position which would correspond to the highest elevation of the arm in the normal state; and the inferior, on the contrary, was in a position which corresponded to its greatest depression.

Dislocations.—The head of the humerus

may be dislocated from the glenoid cavity of the scapula as the result of accident, in three different directions; namely, downwards and inwards, into the axilla.

Secondly, forwards and inwards.

Thirdly, backwards on the infra-spinatus fossa, or on the dorsum of the scapula.

Partial dislocations, or subluxations of the head of the humerus, as the result of accident, have been much spoken of, and accounts of such supposed accidents are to be found in the works of practical surgeons. While we would not deny that cases deserving the name of partial luxations of the head of the humerus do occasionally present themselves to the surgeon, in our experience all such cases have been found, on strict inquiry, not to have been the direct effect of accident, but the result of chronic disease, or of congenital malformation of the shoulder joint. And we here formally deny that the case of partial luxation of the head of the humerus, as the result of accident, has ever been satisfactorily proved, either in the living or the dead subject.

1. — *Dislocation downwards and inwards into the axilla.* — The dislocation of the humerus *downwards* is unquestionably the most common, and is generally produced by a fall on the elbow, or palm of the hand, the arm being at the time extended from the body. The humerus, therefore, immediately prior to the accident, would be so related to the glenoid cavity as to form with it an acute angle inverted; and the head of the bone, thus gliding from above downwards, is forced violently against the lower part of the capsule, which is stretched and lacerated so as to allow the head of the humerus to escape; this result is further aided by the weight of the body, and by the contraction of the great pectoral, latissimus dorsi, and teres major muscles. The new position assumed by the head of the dislocated bone is on the inner side of the anterior margin of the scapula, between the subscapular muscle anteriorly, and the long head of the triceps, posteriorly. The pectoralis major, latissimus dorsi, and teres major muscles act upon the arm as on a lever, of which the elbow is the fulcrum, and the point of resistance is at the articulation; while the elbow rests on the ground, and the weight of the body presses on the lower part of the capsular ligament of the shoulder joint, the muscular folds of the axilla being instinctively thrown into violent action, make an effort to approximate the arm to the side; but as these muscles cannot move the lower extremity of the humerus, on account of the elbow resting on the ground, the head of the bone becomes the moving point, and bursts through the lower part of the capsular ligament, and is dislocated into the axilla. Dislocation *downwards* may, according to some authors, be produced by a violent blow on the outer part of the shoulder, below the acromion; but in that case it is often complicated with fracture of the scapula or humerus. It is further possible that it may result from simple muscular action, as in the act of lifting a heavy weight, or during an attack of epilepsy; in either case a violent effort is required, whether the effect be attributed to the agency of the deltoid, in depressing the head of the bone, or, as Boyer supposes, to the action of the great pectoral, latissimus dorsi, and teres major muscles, simultaneously cooperating with the elevators of the arm.

Symptoms. — The usual signs of this dislocation into the axilla, are the following: — A hollow is formed below the acromion, in consequence of the displacement of the head of the humerus from the glenoid cavity. The deltoid muscle is flattened and dragged down with the depressed head of the bone, so that the natural roundness of the region of the shoulder is lost. The arm is somewhat longer, and the anterior fold of the axilla is deeper than natural, because the new situation occupied by the head of the bone on the subscapular fossa of the scapula, is below the level of its natural position in the glenoid cavity (*fig.* 434.). The elbow is with difficulty made to touch the patient's side; this movement is the source of much pain, as it causes the head of the dislocated bone to compress the nerves in the axilla; and upon this account the patient himself supports his arm at the wrist with the other hand. The head of the os humeri can be felt in the axilla, but not except the elbow be considerably removed from the side. "I have," says Sir Astley Cooper, "several times seen surgeons deceived in these accidents, by thrusting the fingers into the axilla, when the arm is close to the side, when they have directly said, 'This is not a dislocation;' but upon raising the elbow from the side, the head of the bone could be distinctly felt; for that movement throws the head of the bone downwards, and more into the axilla." The surgeon finds some difficulty in overcoming the fixedness of position of the humerus in its new situation. The patient's voluntary power of abduction of the arm, and of rotation, are lost; the motion of the limb forwards and backwards is preserved. There is great difference in respect to the movements which can be communicated to the limb, depending on the tone of the muscles; because, if the muscles are relaxed and feeble, from age or any other cause, the surgeon may be able to move the patient's arm freely, and to raise it up to the head, and even press the elbow close to the side. On moving the limb, a slight crepitus will sometimes be felt, but by a continuance of the motion, this soon ceases; the crepitus, however, in these cases is never like the rough grating which is felt when a fracture is examined. The direction of the longitudinal axis of the arm is changed; for the lower extremity of the humerus being placed outwards from the side, its longitudinal axis, if prolonged upwards, instead of passing towards the glenoid cavity, may be observed to be directed inwards towards the axilla. In this accident, numbness of the fingers is sometimes complained of, arising from the pressure of the head of the

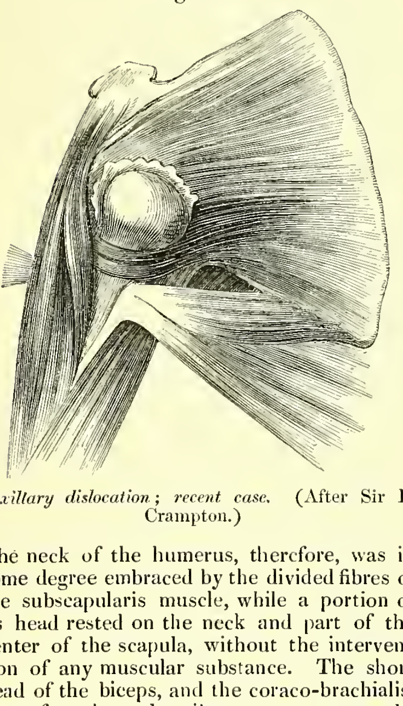
bone upon some of the nerves of the brachial plexus.

Anatomical characters of the dislocation into the axilla. — Sir Astley Cooper informs us that he dissected two recent cases of this dislocation :—" First case : A sailor fell from the yard-arm on the ship's deck, injured his skull, and dislocated the arm into the axilla. He was brought into St. Thomas's Hospital in a dying state, and expired immediately after. On the next day the shoulder joint was minutely examined, and the following were the appearances found :—On removing the integuments, a quantity of extravasated blood presented itself in the cellular membrane, lying immediately under the skin, and in that which covers the axillary plexus of nerves, as well as in the interstices of the muscles, extending as far as the cervix of the humerus, below the insertion of the subscapularis muscle. The axillary artery and plexus of nerves were thrown out of their course by the dislocated head of the bone, which was pushed backwards upon the subscapularis muscle. The deltoid muscle was sunken, with the head of the bone. The supra-and infra-spinati were stretched over the glenoid cavity and inferior costa of the scapula. The teres major and minor had undergone but little change of position; but the latter, near its insertion, was surrounded by extravasated blood. The coraco-brachialis was uninjured. In a space between the axillary plexus and coraco-brachialis, the dislocated head of the bone, covered by its smooth articular cartilage and by a thin layer of *cellular membrane, appeared.* The capsular ligament was torn on the whole length of the inner side of the glenoid cavity, and would have admitted a much larger body than the head of the os humeri through the opening. The *tendon* of the subscapularis muscle which covers the ligament, was also extensively torn. The opening of the ligament, through which the tendon of the long head of the biceps passed, was rendered larger by laceration, but the tendon itself was not torn. The head of the os humeri was thrown on the inferior costa of the scapula, between it and the ribs, and the axis of its new situation was about *an inch and a half below* the centre of the glenoid cavity from which it had been thrown. *The second case,*" adds Sir Astley Cooper, " which I had an opportunity of examining, was one in which the dislocation had existed five weeks, and in which very violent attempts had been made to reduce the dislocated bone, but without success. The subject of the accident was a woman, fifty years of age. All the appearances were distinctly marked ; the deltoid muscle being flattened, and the acromion pointed ; the head of the bone could also be distinctly felt in the axilla. The skin had been abraded during the attempts at reduction, and the woman apparently died from the violence used in the extension. Upon exposing the muscles, the pectoralis major was found to have been slightly lacerated, and blood was effused amongst its fibres; the latissimus dorsi and teres major were not injured ; the supra-spinatus was lacerated in several places ; the infra-spinatus and teres minor were torn, but not to the same extent as the former muscle ; some of the fibres of the deltoid muscle, and a few of those of the coraco-brachialis, had been torn, but none of the muscles had suffered so much injury *as the supra-spinatus.* The biceps was not injured. Having ascertained the injury which the muscles had sustained in the extension, and, in some degree, the resistance which they opposed to it, I proceeded to examine the joint. The capsular ligament had given way in the axilla, between the teres minor and subscapularis muscles; the tendon of the subscapularis was torn through at its insertion into the lesser tubercle of the os humeri, and the head of the bone rested upon the axillary plexus of nerves and the artery. Having determined these points by dissection, I next," says Sir Astley Cooper, " endeavoured to reduce the bone, but finding the resistance too great to be overcome by my own efforts, I became very anxious to ascertain its origin. I therefore divided one muscle after another, cutting through the coraco-brachialis, teres major and minor, and infra-spinatus muscles. Yet still the opposition to my efforts remained, and with but little apparent change. I then conceived that the deltoid must be the chief cause of my failure, and, by elevating the arm, I relaxed this muscle ; but still could not reduce the dislocation. I next divided the deltoid muscle, and then found the *supra-spinatus muscle* my great opponent, until I drew the arm directly upwards, when the head of the bone glided into the glenoid cavity. *The deltoid and supra-spinatus muscles* are those which most powerfully resist reduction in this accident." This dissection explains the reason why the arm is sometimes easily reduced, soon after the dislocation, by raising it suddenly above the horizontal line, and placing the fingers under the head of the bone, so as to lift it towards the glenoid cavity, which will sometimes prove effectual, because, in this position, the muscles are relaxed, so as no longer to offer any resistance to reduction. Sir Philip Crampton has adduced an example of dislocation of the shoulder joint, which illustrates in a satisfactory manner the anatomy of a recent case of dislocation into the axilla.

Case.—" In the year 1808, a labouring man was brought into the County of Dublin Infirmary in a dying state: the persons who carried him stated that he had been engaged in digging under the foundation of a house that had been burned ; that a part of a partition wall fell upon him, and that they had found him buried under the rubbish : the man did not survive more than two hours. On examining the body *eighteen hours* after death, it was observed, that in addition to the injury of the head, which had proved fatal, the right humerus was dislocated into the axilla. To this part I directed the whole of my attention. I made a careful dissection of the joint, previously to reducing the dislocation, and was so fortunate as to obtain a drawing of the

parts, executed upon the spot, by a distinguished artist. On removing the integuments of the axilla, the cellular membrane, which was extensively ecchymosed, formed a kind of cap, closely embracing the head of the os humeri, which, when the axilla was cleared, was seen lodged on the inferior costa of the scapula, or rather, on its neck; the head of the bone, in escaping from its socket, had pushed the teres minor downwards, and burst through the *lower part* of the subscapularis muscle, some of the fibres of which closely embraced the neck of the bone, while the bulk of the muscle was *pushed upwards*, and detached from the inner surface of the scapula (*fig.* 434.).

Fig. 434.



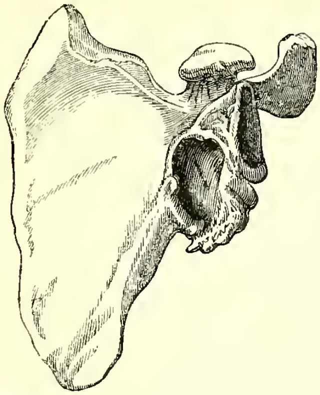
Axillary dislocation; recent case. (After Sir P. Crampton.)

The neck of the humerus, therefore, was in some degree embraced by the divided fibres of the subscapularis muscle, while a portion of its head rested on the neck and part of the venter of the scapula, without the intervention of any muscular substance. The short head of the biceps, and the coraco-brachialis, were forced to describe a curve outwards, over the neck of the humerus on the sternal side, while the long head of the triceps crossed the neck of the bone obliquely on the dorsal side; this strangulation of the head of the bone, by the surrounding muscles, was made most apparent when extension was applied to the fore-arm. The biceps and triceps seemed then to close behind the head of the bone, and interpose themselves between it and the glenoid cavity; the tendon of the long head of the biceps remained in its groove, but the sheath in which it runs was partially ripped up. The capsular ligament was completely torn from the lower part of the neck of the humerus, to the extent of more than half its circumference, the torn edge appearing like a crest over the head of the bone. The great nerves and blood vessels of the arm were forced to describe a curve backwards, by the pressure of the head of the bone, which was in contact with them. But the greatest injury had been sustained by the '*articular muscles*,' as they have been called, which lie on the back of the scapula. The tendons of the supra-spinatus, the infra-spinatus, and the teres minor, were completely torn off from the humerus, carrying with them, however, a scale of bone, which was ascertained to be the surface of the greater tubercle into which they are inserted."

In order to ascertain the nature of the obstacles which oppose the reduction of the dislocated humerus, the scapula was fixed, and the arm being raised to nearly a right angle with the body, extension was slowly applied to the arm by pulling at the wrist; it then appeared that so long as the hand was held *supine*, the head of the bone remained immovable; the chief resistance appearing to be caused by the closing of the biceps and triceps behind the head of the bone. The muscles of the back of the scapula being detached from the greater tubercle, could of course afford no resistance; but, on turning the hand into the *prone* position, and giving a motion of rotation inwards to the whole limb, the extension being still maintained, the head of the bone glided easily into its socket. The appearances observed in this case are nearly identical with those which are described by Mr. Henry Thompson, in the Medical Observations and Inquiries, while they differ materially from those which were found by Sir Astley Cooper; establishing an important fact, which, indeed, might have been inferred *à priori*, that in *apparently* similar dislocations of the humerus, there may be very different *kinds* as well as *degrees* of lesion, and consequently very different causes of resistance to reduction. " In Mr. Thompson's case," Sir P. Crampton adds, " as in mine, the head of the bone was found lodged on the inside of the neck of the scapula, between the subscapularis and teres major muscles; but during the eighteen days which had elapsed since the injury had been received, the *cellular substance of the axilla* had formed a kind of capsular ligament, which embraced the head of the bone, and contained a small quantity of mucus resembling synovia. In Mr. Thompson's case, the capsular ligament was completely torn from the whole circumference of the humerus. In mine it was detached to the extent of more than half the circumference. In both cases, the attachments of the tendons of the supra- and infra-spinatus muscles were torn off with the part of the bone they were inserted into; in both cases, some fibres of the subscapularis muscle embraced the neck of the bone." In Sir Astley Cooper's cases, on the contrary, although the tendon of the subscapularis was torn through, the supra- and infra-spinatus muscles retained the connection with the greater tubercle, and "*until this muscle was relaxed, by raising the arm, the humerus could not be reduced by any efforts which he* (Sir Astley) *could make*." In cases of dislocation of the humerus into the axilla, which have been left long unreduced,

the head of the bone is found altered in its form, the surface towards the scapula being flattened, a complete capsular ligament en-

Fig. 435.



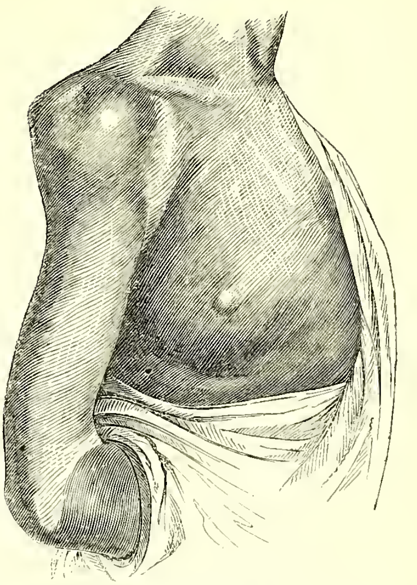
Axillary dislocation; case of long standing.

virons the head of the os humeri. The glenoid cavity is filled entirely by ligamentary matter, in which are to be found small portions of bone. These must be of new formation, as no portion of the scapula or humerus is broken. A new cavity is formed for the head of the os humeri on the inferior costa of the scapula, but this is shallow, like that from which the os humeri had escaped.

2. *Dislocation forwards.*—This species of dislocation is much more distinctly marked than the former. The acromion is more pointed, and the hollow below it, from the depression of the deltoid, is more considerable. The head of the os humeri can be felt through the skin and pectoral muscle, and its convexity seen, in thin persons, just below the clavicle; and when the arm is rotated, the protuberance may be observed also to rotate and accompany the motions of the arm. The coracoid process of the scapula is placed above and on the outside of the head of the bone, which we know is covered by the pectoris major muscle. The elbow is thrown out more from the side, and further back than it is in the case of dislocation into the axilla (*fig.* 436.).

Much difference of opinion seems to prevail as to whether the arm is lengthened or shortened, as the result of this dislocation of the head of the humerus forwards. Malgaigne and Dupuytren both assert that the arm on the dislocated side is longer than natural; Sir A. Cooper expresses himself in opposite terms; he says, that in the dislocation forwards and inwards of the head of the humerus, the arm is shortened. In our experience we have never found in the living subject the arm shortened; and in the specimen from which *fig.* 436. has been taken, the centre of the new glenoid cavity is several lines *below* the centre of the original cavity, and the arm therefore must have been by, so much, longer than natural. The direction of the longitudinal axis of the limb passing from below upwards, is much altered, being thrown

Fig. 436.



Dislocation of the head of the humerus forwards and inwards.

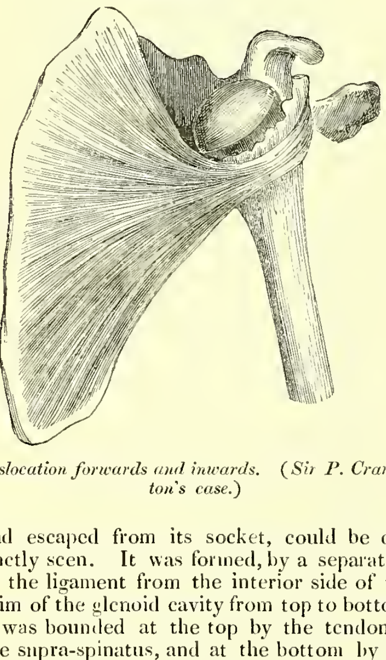
inwards towards the middle of the clavicle. The pain attending this accident is less than it is in the case where the head of the bone is thrown into the axilla, because the nerves of the axillary plexus are less compressed; but the motions of the joint are much more materially affected. The strongest diagnostic marks of the dislocation are these. The elbow is separated from the side and thrown backwards, and the head of the humerus can be felt to move below the clavicle when the arm is rotated. Sir Philip Crampton has adduced the following example of the ordinary dislocation forwards, in which the head of the bone was thrown at *once* on the neck of the scapula, without previously passing into the axilla.

"James Wilson, æt. 30, fell into a limekiln, in the immediate neighbourhood of the Meath Hospital, while the lime was still burning; he was drawn up by ropes, but just as he reached the top of the shaft, the rope broke, and he again fell to the bottom, a distance of about fifteen feet, on the ignited stones. It appeared, on examination, made in the Mea h Hospital, that in addition to several extensive burns and lacerations, there was a dislocation of the humerus, under the pectoral muscle. Mr. Macnamara, without assistance, reduced the dislocation, by merely drawing the arm gently forwards and downwards with one hand, while he pushed the head of the bone towards the glenoid cavity with the other. The man died in the course of the day, from the conjoint effects of the burn and the fall. Eighteen hours after death the

shoulder joint was *dissected* by Mr. Macnamara, from whom I take the description of the appearances, with the advantage of having the preparation before me while I write.

The dislocation was unattended with rupture of any muscle, or the separation of any tendon from its insertion into the bone; by a slight effort the dislocation was reproduced, and the pectoral muscles being removed, the polished head of the bone was now seen lodged on the cervix of the scapula, at the root of the coracoid process, but extending nearly as far as the notch in the superior margin of the scapula. The head of the bone had passed out through a rent in the capsular ligament, *over the upper edge* of the tendon of the subscapularis, detaching this muscle from its connection, which is at this point but slight, with the inner surface of the scapula, and pushing its fibres *downwards*, so that they formed a curve, which partly embraced the neck of the humerus (*fig.* 437.). The supra- and infra-spinatus muscles were on the stretch, but had suffered no injury. The cellular substance covering their tendons was deeply ecchymosed, so as to mark their course most distinctly. On replacing the head of the bone, the opening in the capsular ligament through which it

Fig. 437.



Dislocation forwards and inwards. (*Sir P. Crampton's case.*)

had escaped from its socket, could be distinctly seen. It was formed, by a separation of the ligament from the interior side of the brim of the glenoid cavity from top to bottom, it was bounded at the top by the tendon of the supra-spinatus, and at the bottom by the inferior edge of the tendon of the subscapularis; the rent was continued as far as the root of the lesser tubercle of the os humeri, and was of sufficient extent, but no more, to permit the head of the bone to pass easily through it. The inferior part of the capsular ligament, however, the part corresponding to the axilla, was perfect. The great blood vessels and nerves lay to the sternal side of the head of the humerus, and were forced a little out of their course. The axis of the head of the bone in its disturbed position was scarcely a quarter of an inch higher than the axis of the glenoid cavity.

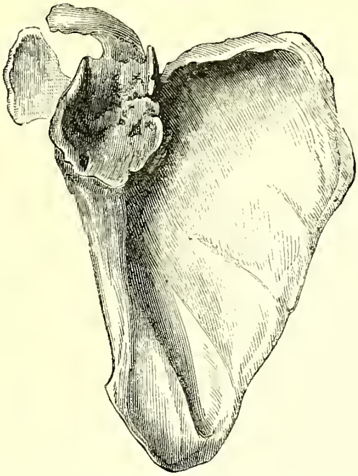
Sir P. Crampton observes, "the anatomy of the recent case of dislocation *forwards* settles the long disputed question as to whether or not the humerus can be dislocated *primitively* in any other direction than *downwards*, or into the axilla; it is plain, that in the case of Wilson, the head of the bone was thrown at once forwards, into the situation into which it appears under the clavicle; as the inferior portion of the capsular ligament was not ruptured, and the attachment of the subscapularis and teres minor muscles to the inferior costa of the scapula remained undisturbed."

Mr. Key has given the following account of the appearances observed in dissection of the right shoulder joint of a patient who had had for seven years an unreduced dislocation of the head of the humerus, in the direction forwards and inwards. The specimen is preserved in the museum attached to St. Thomas's Hospital. The head of the bone was thrown on the neck and part of the venter of the scapulæ, near the edge of the glenoid cavity, and immediately under the notch of the superior costa: nothing intervened between the head of the humerus and the scapula, the subscapularis muscle being partly raised from its attachment to the venter. The head was situated on the inner side of the coracoid process, and immediately under the edge of the clavicle, without having the slightest connection with the ribs; indeed, this must have been prevented by the situation of the subscapularis and serratus magnus muscles between the thorax and humerus. The tendons of all the muscles attached to the tubercles of the humerus were perfect, and are shown in the specimen preserved. The tendon of the biceps was not torn, and it adhered to the capsular ligament. The glenoid cavity was completely filled up by ligamentous structure, still however preserving its general form and character; the tendons of the supra- and infraspinati and teres minor muscles adhered by means of bands to the ligamentous structure occupying the glenoid cavity, and, to prevent the effects of friction between the tendons and the glenoid cavity in the motions of the arm, a sesamoid bone had been formed in the substance of the tendons; the newly formed socket reached from the edge of the glenoid cavity to about one-third across the venter; a complete lip was formed around the new cavity, and the surface was irregularly covered with cartilage. The head of the bone had undergone considerable change of form, the cartilages being in many places absorbed, and a complete new capsular ligament had been formed."

The accompanying wood-cut (*fig.* 438.) is taken from a scapula preserved in the museum of the College of Surgeons in Dublin, and re-

sembles much the specimen alluded to by Mr. Key. The newly formed socket reached from

Fig. 438.

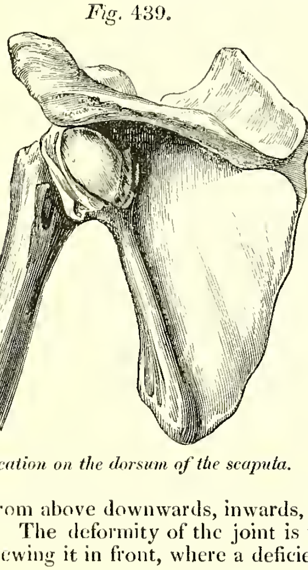


Dislocation forwards and downwards. (Original, from the museum of the College of Surgeons, Dublin.)

the edge of the glenoid cavity, to about one-third across the subscapular fossa; a deep cup was formed for the reception of the dislocated head of the humerus; the inner margin of this cup was fully half an inch above the level of the subscapular fossa; the glenoid cavity had lost all cartilaginous investment; it was rough on its surface from bony deposition, and its inner margin was elevated somewhat into a sharp ridge, so as to form part of the margin of the new articular cavity for the head of the humerus.

3. *Dislocation backwards of the head of the humerus on the dorsum of the scapula, the result of accident.* — In this dislocation the arm is

Fig. 439.



Dislocation on the dorsum of the scapula.

directed from above downwards, inwards, and forwards. The deformity of the joint is well seen by viewing it in front, where a deficiency is noted of the normal roundness of the articulation. When we look at the shoulder sideways, the head of the humerus may be seen to form a remarkable saliency *behind* the posterior angle of the acromion. In this dislocation the head of the bone is thrown on the posterior surface of the scapula immediately below the spine of this bone, and there forms a very remarkable protuberanee, and when the elbow is rotated as far as practicable this protuberance moves also. The dislocated head of the bone may be easily grasped between the fingers, and distinctly felt resting below the spine of the scapula; the motions of the arm are impaired, but not to the same extent as in the other luxations of the shoulder, and the longitudinal axis of the humerus may be observed to run upwards, backwards, and to a point, evidently behind the situation of the glenoid cavity. In Guy's Hospital Reports* Sir A. Cooper has published a case of this species of dislocation, from which we abstract the following.

Case. — " Mr. Key has given me the particulars of the following case. Mr. Complin was 52 years of age, and had been the subject of epileptic fits; one of them, which was particularly severe, occurred one morning while he was in bed, and in his violent convulsive strugglings his shoulder became dislocated on the dorsum of the scapula, presenting the ordinary symptoms of this accident in which dislocation had never been reduced." The circumstance most peculiar in this case was, that the head of the bone could by extension be drawn into its natural situation in the glenoid cavity; but so soon as the force ceased to be applied it slipped back again in the dorsum of the scapula, and all the appearances of dislocation were renewed. The second peculiarity consisted in a sensation of crepitus as the bone escaped from its socket, so as to lead to a belief that the edge of the glenoid cavity had been broken off. The patient was unable to use or even to move the arm to any extent, nor could he by his own efforts elevate it from his side, and although he lived seven years after the occurrence of the epileptic fit, he never recovered the use of the limb. Mr. Key sent the following note of the dissection of the dislocated shoulder in this case to Sir A. Cooper: —" The dislocation of Mr. Complin's shoulder arose from muscular action alone in a paroxysm of epilepsy, and during his life it was thought probable that a portion of the glenoid cavity had been broken off, or a piece of the head of the os humeri, or perhaps the smaller tubercle, and that either of these injuries would account for the head of the bone not remaining in its natural cavity when reduced. But the inspection, *post-mortem*, proved that the cause of this symptom was the *laceration of the tendon of the subscapularis muscle*, which was found to adhere to the edge of the glenoid cavity, and was much thickened and altered in its character from its laceration, and from its very

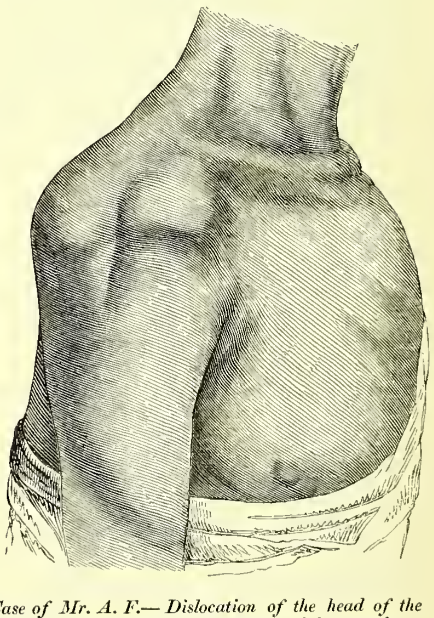
* Astley Cooper on Dislocations, &c., page 384., edition 1842, by Mr. B. Cooper.

imperfect and irregular union. The muscles of the dorsum scapulæ were diminished, by being thrown out of use, and the tendon of the long head of the biceps muscle was entire, but glued down by adhesion." Upon further examination of the scapula and os humeri, Sir A. Cooper found the muscles and the situation of the bones to be as follows: — "The head of the os humeri was placed behind the glenoid cavity of the scapula, and rested upon the posterior edge of that articular surface, and upon the inferior costa of the scapula, where it joins the articulation. When the scapula was viewed anteriorly, the head of the os humeri was placed in a line behind the acromion but below it, and a wide space intervened between the dislocated head of the bone and the coracoid process, in which the fingers sunk deeply towards the glenoid cavity of the scapula. When viewed posteriorly, the head of the os humeri was found to occupy the space between the inferior costa and spine of the scapula, which is usually covered by the infraspinatus and teres minor muscles. The tendon of the subscapularis muscle, and the internal portion of the capsular ligament, had been torn at the insertion of that muscle; but the greater part of the posterior portion of the capsular ligament remained, and had been thrust back with the head of the bone, the back part of which it enveloped. The supraspinatus muscle was put upon the stretch, the subscapularis was diminished by want of action, and the infra-spinatus, and teres minor muscles were shortened and relaxed, as the head of the bone carried their insertions backwards. The tendon of the long head of the biceps muscle was carried back with the head of the bone, and elongated; but it was not torn. As to the changes in the bones, the head of the os humeri, and the outer edge of the glenoid cavity of the scapula, were in direct contact, the one bone rubbing upon the other when the head of the os humeri was moved; and this accounted for the sensation of crepitus at the early period of the dislocation, as there was no fracture. The glenoid cavity was slightly absorbed at its posterior edge, so as to form a cup, in which the head of the bone was received, and this latter bone and the articular cartilage had been in some degree absorbed where it was in direct contact with the scapula, as well as changed by attrition during the seven years the patient lived." The surface of the original glenoid cavity, instead of being smooth and cartilaginous, was rough and irregular, having elevations at some parts, and depressions at others. The extremity of the acromion was sawn off, to look for any little fragment of bone which might have been broken off, but not the smallest fracture could be perceived.

Mr. Key, in his account of another case of dislocation of the os humeri backward on the dorsum of the scapula, writes as follows: — "I found a very stout man sitting up in bed in great pain, and complaining more than patients commonly do under dislocation, and I concluded it to be some fracture about the cervix, especially as at first view nothing could be seen of a hollow under the deltoid muscle, the joint appearing round as usual. On passing to the man's side to examine the limb, the deformity of the shoulder became visible, the forepart appeared flattened, and the back of the joint fuller than natural: the head of the bone could be seen as well as felt, resting on the posterior part of the cervix scapulæ. The elbow could be brought to the side, or raised on a level, with the acromion. Rotation *outwards* was entirely impeded, in consequence of the subscapularis being stretched, all motions of the limb giving him extreme pain, which was referred to the lower part of the deltoid muscle, in the direction of the articular nerves, which were probably injured by the pressure of the head of the bone."

The dislocation of the head of the humerus backwards on the dorsum of the scapula is said to be very easily recognised, yet the writer has seen two examples of it which had been overlooked at the moment of the accident, and he has heard of two others. When the swelling, the result of the laceration of parts, has subsided, the nature of the injury becomes very evident indeed. A gentleman, Mr. A. F., aged about 35 years, called upon the writer four years ago to examine his shoulder. He stated that he was thrown off a jaunting car about three months previously, and injured his shoulder, and that ever since he had had but very imperfect use of his arm. The patient had been educated as a medical man, had practised surgery, but did not himself suspect the nature of the injury, when,

Fig. 440.



Case of Mr. A. F.— Dislocation of the head of the humerus backwards on the dorsum of the scapula.

about ten weeks after the accident, he called upon the writer. The nature of the injury

was very manifest. The arm was placed close to the side, was neither lengthened nor shortened; he had no pain in the shoulder joint, but had very imperfect use of the limb. The shoulder had not the flat appearance externally surmounted by the prominent angle formed by the acromion, which characterises the axillary dislocation; nor had he the fulness beneath the clavicle and in front of the acromion which are noticed in the dislocation forwards; on the contrary, a deficiency was observed in front beneath the acromion; and here the fingers could be sunk into a deep fossa, which seemed to extend even to the unoccupied glenoid cavity; while behind the posterior angle of the acromion a tumor as large as an orange could be seen and felt (*fig.* 440.). This rounded prominence moved with the shaft of the humerus; a well-marked vertical groove showed the distinction between the convexity which belonged to the head of the dislocated humerus behind and that which formed the posterior angle of the acromion (*fig.* 440.).

An energetic attempt was made at the Richmond Hospital to reduce the dislocation in this case three months after the accident had occurred, but without success.

Diagnosis between fractures of the superior extremity of the humerus and dislocations of the shoulder-joint.—As we have already pointed out the symptoms which are peculiar to each of the forms of scapulo-humeral dislocations, we may here direct attention to the fact, that these symptoms are very similar to those which belong to fracture of the upper extremity of the humerus: so that in many cases the difficulty of distinguishing between these different injuries is such as to lead not uncommonly to a false diagnosis. Every person labouring under either a fracture or luxation of the superior extremity of the humerus, informs us that he has fallen on that side of the body on which the injury exists; but the position of the arm at the moment of the accident will be found to have been different in the case of fracture and dislocation: so that if we know how the limb was placed at the moment of the fall, we may be led to conjecture from this alone the nature of the accident which has occurred. If, for example, when the patient is falling, his arm is separated from his body directed forwards, or outwards, as it were instinctively to break the fall, and save the upper part of the body, if under these circumstances displacement of the upper part of the humerus occurs, the existing deformity will be found to be the result of dislocation; but if, on the contrary, the fall takes place when the arm is by the side, as, for instance, in the breeches pocket, and no effort is made by the patient, at the moment of the fall, to raise the arm, the momentum and weight of the body have been received on the point of the shoulder, the resulting injury has been most probably a fracture of the head and upper part of the humerus. In both cases the pain experienced at the shoulder is severe, and gives rise to the impression, on the patient's mind, that he fell on that part; but if the patient has met with a dislocation, it will be found that in reality he has fallen on the palm of the hand, evidences of which the surgeon will be better able to discover in the excoriations which the palm has suffered, than by any report which the patient himself may be enabled to make. When the patient has met with a fracture, we shall, on inquiry, discover that the fall has taken place on the outside of the shoulder; there is, in this case, no abrasion of the palm of the hand, while considerable tumefaction and extensive ecchymosis, the effects of contusion, are observable along the outer side of the arm. When called to the patient immediately after the accident, we notice those circumstances as to the hand and clothes which will instruct us as to the probability, whether the patient had fallen forwards on the palm of the hand, or completely outwards on the stump of the shoulder. In case of fracture, moreover, there is extensive ecchymosis; in simple dislocation, little, if any; but if it should exist, it is rather on the anterior and internal part of the limb, than on the outside, as in fracture. In both fracture and luxation the acromion is salient, and the deltoid flattened; but as the displacement is more complete in luxation than in fracture, the prominence of the acromion and the depression beneath it are more marked in the former than in the case of fracture. When there is a luxation, and we wish to impart movements to the limb, the humerus often moves in connection with the scapula, as if the two bones made but one body. If there is a fracture, there is abnormal mobility at one point in the upper part of the humerus. This mobility is ordinarily accompanied by a crepitus which is best elicited by seizing the inferior extremity of the humerus at the elbow and rotating it on its long axis.

Finally, great efforts are frequently necessary to effect a reduction of the dislocated humerus; but once replaced, the bone remains in its proper articular cavity, and the deformity of the shoulder does not recur; but in fracture, although the bone may be replaced with comparative facility, yet, if it be left unsupported, the deformity will almost immediately recur. In the case in which it is not easy to distinguish a fracture from a luxation, Dupuytren gives the precept — "Rendez au membre, par des manœuvres convenables, sa forme et sa longueur naturelles; retournez auprès du malade sept ou huit heures après : si vous trouvez l'épaule déformée, soyez assuré que vous avez à faire à une fracture." *

Malgaigne has made the observation, that in all luxations of the head of the humerus, the head of the bone must descend below its ordinary level, and consequently that, no matter which of the three dislocations has occurred, the dislocated arm must be longer than the other. This appears to us

* Leçons Orales.

to be a point, by attention to which we may be assisted in our endeavours to establish the diagnostic marks between dislocation and fracture, because, in fracture of the humerus, we have almost invariably found, whether from some overlapping of the bones, or impaction of one of the fragments into the other, that some *shortening* of the arm exists. If there be dislocation, the arm is sometimes abnormally lengthened, and never shortened. In the measurement of the injured limb we have therefore a simple means to resort to, which will no doubt assist us much in making our diagnosis.

4. We have heretofore adverted only to the ordinary symptoms and anatomical characters belonging to the three dislocations which the head of the humerus is liable to; but practical surgeons have, however, noticed that *a dislocation of the head of the humerus is sometimes combined with a fracture of this bone.* In this case the fracture 'may sometimes engage merely the tuberosities, sometimes the anatomical, and sometimes the surgical neck of this bone. It has been long ago noticed by Thompson *, that when the head of the humerus is dislocated into the axilla, the greater tuberosity of this bone, which gives attachment to the three posterior capsular muscles, is torn off from the shaft of the humerus, and left attached to these muscles. This observation of Thompson has since been repeated by others, from amongst whom we have already quoted a case adduced by Sir Philip Crampton, of an axillary dislocation, in the dissection of which it was found that the tuberosities were detached. Such a complication with a dislocation of the humerus would no doubt facilitate the reduction of the dislocated bone, but its subsequent maintenance in its place would be thereby rendered very difficult.

We have reason to believe that a fracture, completely detaching the greater tuberosity of the humerus, may be combined with a dislocation forwards; and in this case, although the dislocation may be reduced, the head of the humerus cannot be maintained in the glenoid cavity. We have for some time considered this to be the explanation of the specimen contained in the Richmond Hospital Museum, an account of which we find given by Dr. R. Smith, and from which we abstract the following:—"Upon removing the soft parts, the head of the bone presented itself, lying partly beneath, and partly internal to the coracoid process. The greater tuberosity, together with a very small portion of the outer part of the head of the bone, had been completely separated from the shaft of the humerus. This portion of the bone occupied the glenoid cavity, the head of the humerus having been drawn inwards, so as to project upon the *inner* side of the coracoid process; it was still contained within the capsular ligament, which was thickened and enlarged, and bone had been deposited in its tissue. A new and shallow socket had been formed upon the costal surface of the neck of the scapula, below the root of the coracoid process, and the inner edge of the glenoid cavity, the tuberosity was united to the shaft only by ligament. The injury had occurred many years before the death of the patient, but the history of the case was not precisely known."

But fracture of the greater tuberosity may also occur, as a consequence of falls on the outer side of the shoulder, or otherwise, without any dislocation following.

Fracture of the *lesser* tuberosity of the humerus may, we suppose, be an accident likely to attend on dislocations of the head of this bone, and would, we imagine, be attended with consequences similar to those which followed the laceration of the tendon of the subscapularis muscle in a case of dislocation on the dorsum of the scapula, noticed by Sir A. Cooper and Mr. Key.

Dislocation of the head of the humerus, accompanied with a fracture of the neck of the humerus. — Sometimes the luxation of the humerus is complicated with a fracture of the anatomical or surgical neck of this bone; we have then one of those rare lesions to deal with, for which nature and art can do but little. In such a case it is plain that the dislocation has first occurred. When there is both a dislocation and fracture, Sir A. Cooper says, the symptoms resemble those which usually accompany the dislocation into the axilla, the head of the bone being there felt; but there is somewhat less of the hollow to be observed below the acromion, and the deltoid muscle does not seem much depressed, because the broken extremity of the shaft quits the head and lodges in the glenoid cavity of the scapula. Upon rotating the arm, the broken shaft of the bone can be perceived to move under the acromion; there is but little power of motion; and considerable pain is felt not only in the shoulder, but in the arm and hand. The head of the os humeri can be felt when the arm is raised, and the surgeon's fingers are introduced into the axilla; but when the arm is rotated at the elbow, the head of the bone remains entirely unmoved, or very little obedient to the motions of the elbow. In some cases, but not always, a distinct crepitus can be perceived.

The broken end of the os humeri is drawn somewhat forwards, but is easily pushed into the glenoid cavity, from which, unless it be supported, it is again drawn by the pectoralis and coraco-brachialis muscles.

The arm, measured from the acromion to the elbow, is shorter than the other.*

As this accident is produced by great violence, the parts are much obscured by the effusion of blood, and by the inflammation which speedily follows; but, for the first three hours, the muscles are so lax, that but for the pain it occasions, considerable motions of the limb might be produced.

* Medical Obs. and Enq. vol. ii. p. 349.

* Smith on Fractures.

In one case detailed by Sir A. Cooper, the tubercles were broken off with the head of the bone, and the fractured extremity of the neck of the os humeri was placed in the glenoid cavity of the scapula. In another case, the fracture was intra-capsular, and the head of the bone was at the same time dislocated forwards, under the pectoral muscle, and placed at the inner side of the coracoid process.

Delpech * gives the history of a case of fracture of the anatomical neck of the humerus, combined with a dislocation. The case was remarkable, and differed from all the others recorded, in being an example of that rare form of dislocation, where the bone is thrown on the dorsum of the scapula. The history of the case is accompanied with an engraving.

With regard to the case of dislocation into the axilla, complicated with fracture, Sir A. Cooper says, "I would observe that in this case the fall and depression of the shoulder is less striking than in the case of simple axillary dislocation, as the shaft of the bone fills up the glenoid cavity; also, that in the case complicated with fracture, the head of the bone can still be distinctly felt in the axilla, and that as it does not move when the os humeri is rotated from the elbow, this becomes the principal diagnostic mark.

"That a grating sensation can generally be felt, and sometimes a very distinct crepitus, especially if the elbow be raised outwards during the rotation of the arm.

"That the upper extremity of the shaft of the humerus can be felt advancing to the coracoid process; but that it is easily returned into the glenoid cavity, and that it there rotates with the arm, but easily again slips forward.

"That the accident which produces it is much more severe than that by which simple dislocation into the axilla is produced; and there is, therefore, more contusion, more swelling, and more pain."

Muscles. — If in some cases the tuberosities of the humerus are broken off and remain connected with the muscles when the head of the humerus is dislocated, in others, we may be prepared to expect that in the dissection of cases of dislocation, the capsular and other muscles will be found lacerated. If, as has been stated, the supra-spinatus be the muscle which is most put on the stretch when the head of the humerus is dislocated downwards, we need not be surprised to learn that this muscle is very frequently found to have been ruptured, or to have torn away a fragment of bone from the head of the humerus.

In the dislocation on the dorsum of the scapula, the dissection of which is detailed in Sir A. Cooper's work, we find the following observations made by Mr. Key, with reference to a very peculiar phenomenon noticed in that case: namely, "that, during the patient's life-time it was thought probable that a portion of the glenoid cavity had been broken off, or a piece of the head of the os humeri, or perhaps the smaller tubercle; and that any of these injuries would account for the head of the bone not remaining in its natural cavity when reduced; but the inspection post-mortem proved that the cause of this symptom was the laceration of the tendon of the *sub-scapularis muscle*, which was found to adhere to the edge of the glenoid cavity, and much thickened and altered in its character from its laceration, and very imperfect and irregular union."

The tendon of the long head of the biceps is sometimes altered, as to its direction, in cases of complete dislocation, and adhesions between it and the contiguous parts occur; but there are very few cases recorded, or to be found in museums, which prove that in true dislocation from accident, the tendon was found ruptured. In this respect, the effects of accident and disease on this tendon are strongly contrasted; for, as the result of disease, the tendon, so far as its articular portion is concerned, is very generally removed altogether.

Besides lesions affecting the bones, muscles, and tendons, injuries of *other tissues* may be found occasionally to accompany or succeed to dislocations of the shoulder.

A dislocation of the head of the humerus may be accompanied with an *œdematous swelling* of the arm and forearm; with a paralysis of the dislocated extremity, or with a laceration of the axillary artery, and a diffused aneurism; it is said also that occasionally an emphysematous swelling of the shoulder has followed the reduction of the dislocation; and on other occasions, that the articular structures have been attacked with very severe *inflammation.* For example, as to this last: Mr. Hunter gives an account of a case of dislocation of the shoulder-joint, which he dissected three weeks after its reduction, from which, if we could be influenced by one case, we might infer that inflammation, though latent, may sometimes be the consequence of a dislocation of the head of the humerus. Mr. Hunter's observation is as follows: "What was very remarkable, and what I did not expect, there *was a good deal of pus in the joint.*" *

Partial or general *paralysis* of the muscles of the arm has also been observed as a consequence of a dislocation of the head of the humerus, particularly when either the circumflex nerve alone, which is that most usually injured, or all the nerves of the brachial plexus have been violently contused, or greatly stretched; or even torn across either at the time of the accident, or by the violence of the means used to restore the luxated humerus, when the dislocation has been left long unreduced. Flaubert, of Rouen, speaks of an *emphysema* of the chest succeeding his efforts to reduce an old luxation of the humerus;

* Clinique Chirurgicale, Paris, tom. i. p. 234.

* Pathological Catalogue of Museum of R. C. Surgeons, England, vol. ii. p. 20. No. 868.

and it is known that Desault had already observed a similar occurrence. A Memoir, containing six cases published in the Repertoire d'Anatomie et de Chirurgie, by M. Flaubert, surgeon in chief to the Hôtel Dieu de Rouen, is not well calculated to encourage practitioners to attempt the reduction of old dislocations. In five of these cases the reduction was followed by serious accidents. M. Flaubert observes, that in many cases when paralysis of the upper extremity had been attributed to the dislocation itself, he believes it was rather owing to the violent efforts made for its reduction; laceration of muscles and extensive abrasion of the skin have been noticed as the consequence of these efforts, and even death from diffuse inflammation has occurred; but these accidents, whether the result of dislocation, or of the means used to restore the bone to its place, must be considered as rare in this country, as from the comments of Mr. Mar, and the observations of the Editors of the Leçons Orales of Dupuytren, they seem to have been in Paris. The latter observes, "Le hasard qui a fourni à M. Flaubert, dans le court espace de trois ou quatre ans, un ensemble de tous les accidens les plus graves qui puissent déterminer la réduction, est vraiment extraordinaire : il faut sans doute en chercher la cause dans des circonstances particulières, qui sont inconnues." *

Alterations of the nerves.—We have noticed as belonging to the symptoms of dislocation of the head of the humerus, that the patient complains of pain extending down the course of the nerves of the arm and the forearm, and also of numbness. These symptoms generally disappear when the dislocation is reduced, but sometimes they persist. The pressure which the nerves of the axillary plexus undergo has naturally been referred to as the cause of these unpleasant symptoms. The nerves, besides being stretched, have been sometimes even torn across; when this has occured the effects produced must long remain; such cases are very rare. Among all the nerves in the vicinity of the shoulder-joint which have been referred to as the seat of injury the result of luxation of the humerus, the *circumflex nerve*, which supplies the deltoid, is that which has been found most frequently injured. Indeed, from the manner it winds round the neck of the humerus to arrive at its destination at the under surface of the deltoid muscle, it can scarcely escape being stretched and elongated, and such a lesion of this nerve we may well expect to be followed by a paralysed condition of the deltoid muscle. The circumflex nerve has been found compressed by the dislocated head of the humerus, flattened, and firmly adherent to the capsule of the joint. We find in the Museum of Bartholomew's Hospital, (Catalogue, p. 124, vol. i., No. 42.,) a preparation of a shoulder-joint, exhibiting a dislocation of the humerus, which occurred eighteen months before death. "The head of the humerus rests on the anterior surface, near the inferior border of the scapula. The tendons of all the capsular muscles were entire; the long tendon of the biceps retains its attachment to the glenoid cavity. *The circumflex nerve is compressed by the head of the dislocated bone, and was in consequence flattened, and firmly adherent to the capsule of the joint.* The dislocation had been followed by permanent paralysis of the deltoid muscle."

* Leçons Orales, vol. iii. page 140.

Artery. — Luxations of the head of the humerus have been found complicated with a lesion of the axillary artery. This we believe to be a very rare occurrence. M. Flaubert of Rouen cites cases of this lesion to have occurred in the Hôtel-Dieu de Rouen, as a consequence of the efforts made by surgery to reduce old luxations of the humerus. In the following case, which the writer thinks of sufficient importance to be here introduced, the laceration of the axillary artery was recognised a few minutes after the dislocation had occurred — and before any effort whatever had been made to restore the humerus to its place.

Case. — John Smith, æt. 50, was thrown down by a runaway horse one morning during the summer of 1833; in about ten minutes after this occurred, he was brought to Jervis Street Hospital, when the writer, at that time one of the surgeons of the institution, was prescribing for the extern patients. The man was in a cold perspiration, pallid, and apparently on the verge of syncope. The writer immediately observed that the patient had a dislocation of his left humerus, into the axilla, and, proceeding to point out, as was his custom, to the clinical class the diagnostic marks of the luxation, he noticed that the cavity of the axilla was filled up to a remarkable degree. This *sudden* filling up of the axilla he immediately concluded could be attributed to no other source than to the laceration of a large artery. He quickly sought for the pulse in the radial and brachial artery of the dislocated limb; but no pulsation could be felt in any artery below the site of the left subclavian, while the pulse, though feeble, could be readily felt at the heart, and in every external artery of the system, except in those of the dislocated arm.* The writer then observed to the clinical class, that in this case there were two lesions to be noticed, namely, a dislocation into the axilla, the features of which were very well marked, complicated with *a rupture of the axillary artery;* in a word, besides the dislocation there was a diffused aneurism; the latter was unattended by any pulsation, so that he conjectured the artery was completely torn across. He did not long deliberate as to what course was the best to pursue under existing circumstances, because he felt sure that, so far as the torn artery was concerned, if the head of the humerus was once restored to its place, this vessel would be in at least as favourable a condition

* Mr. Brassington, now a practising surgeon at Port Rouines, was one of those present on this occasion.

as it then was, and secondly that the state of prostration and debility the patient was in, at that moment, offered an opportunity which, if once lost, might not again be afforded, of reducing *easily* the dislocation. Taking the patient, therefore, unawares, the writer placed his knee in the axilla of the dislocated arm, and then slight extension having been made over this fulcrum, the bone at the first trial returned into the glenoid cavity. The patient was placed in bed in the hospital, under the care of the late Mr. Wallace, whose day it was for admitting accidents. There was much more superficial ecchymosis about the axillary, and subclavian region, and along the inside of the left arm, than is usually observed after a simple dislocation of the head of the humerus. The deep axillary swelling remained stationary for some days; but no pulsation could be discovered either in it, or in the arteries of the limb. A feeble and frequent pulse could be felt in the left subclavian, and in all the other arteries, as well as in the heart. After the space of ten days, Mr. Wallace's month of attendance having expired, the case came under the care of Mr. O'Reilly, who having been satisfied that a diffused aneurism existed, and was on the increase, performed the operation, at which the writer was present, of tying the subclavian artery in the third stage of its course. The patient recovered, and was discharged from the hospital about two months afterwards; he lost the last two fingers by gangrene; but whether from an attack of erysipelas, which succeeded the operation, or from the effects of the ligature of the main artery of the limb, is not clearly known. The man lived for many years afterwards, in the immediate vicinity of the Richmond Hospital.

Section 3.—*Congenital malformation of the shoulder joint.* — Although little can be done by medicine or surgery to alleviate, much less to remedy, the evils attending on congenital malformation of the shoulder joint, still it appears to us to be not the less necessary that the abnormal conditions of this articulation resulting from congenital defects should be studied. These, like some other congenital malformations of the joints, attract but little notice during the first months of infancy, but as the child grows the defect becomes more manifest. It very commonly happens in these cases, that after some time the ordinary surgical opinions taken on the case, and the measures recommended failing, as they naturally do, to produce satisfactory results, the ill-fated patient, born with malformation of the shoulder joint, is subjected to ignorant and empirical treatment, the inutility of which too often proves to be the least of the evils attending it.*

The most common form of congenital malformation of the parts composing the region of the shoulder joint that we have noticed, has been apparently the result of an arrest of development, and of atrophy affecting the muscles, the bones, and probably also the nerves of this region. Sometimes we find *both* shoulder joints are malformed in the same individual; generally one only is thus affected. In this last case the atrophied condition of the malformed joint is well seen on comparing the normal and abnormal shoulder: the latter is smaller than the former; the muscles around the joint are so imperfectly developed, that the coracoid and the acromion processes and the head of the humerus become unusually conspicuous. The deltoid and articular muscles are so weak, and the capsule so loose, that the limb seems usually to be drawn down, as it were, by its own weight, and then becomes displaced forwards and inwards beneath the coracoid process, where it habitually remains, the head of the humerus forming a protuberance in front, which yields to the slightest force pressing it backwards towards the usual site of the glenoid cavity of the scapula. When the arm is taken hold of at its lowest extremity, as at the elbow, and drawn backwards, the head of the humerus advances forwards and passes beneath the coracoid process, and a depression, corresponding to the posterior half of the glenoid cavity, is perceptible. On the contrary, when the elbow is drawn forwards, the head of the humerus recedes towards the normal site of the glenoid cavity; when the humerus is raised up perpendicularly towards the acromion, and the influence of the weight of the limb is thus counteracted, the shoulder appears of its natural form, but diminished about half the normal size. The muscles around the joint are so badly developed, that the bony process which surrounds it becomes very conspicuous.

The accompanying drawing is designed to pourtray the general aspect of one of these cases of congenital malformation of the shoulder joint in the displacement inwards of the head of the humerus (*fig.* 441.).

Case. — The following is the history of the case from which the drawing has been taken. M. H., æt. 28, is in every respect healthy and well formed, except as to his left shoulder, which, since his birth, has always been noticed to have been smaller than the other. This defect gives a peculiar appearance to his whole figure as he stands or walks. As his arm hangs by his side, the longitudinal axis of it is directed downwards and a little backwards. The head of the humerus is a little advanced as well as depressed beneath the outer margin of the coracoid process; it is

* About ten years ago the writer met in consultation surgeon W. Wilde on the case of an only child, a girl of thirteen years of age, who had a congenital malformation of the shoulder joint, presenting exactly the appearance of the joint (*fig.* 441.). The young lady is now twenty-three years of age, and the writer has been informed by one of her relatives, that she is in no respect better as to the condition of her shoulder joint; but that her general health has suffered materially in consequence of the various treatment she had been subjected to in vain. Her parents, ignorant of the nature of the case, and too sanguine in their hopes, had been the easy dupes of charlatanism.

also slightly adducted towards the middle line. When the shoulder is viewed posteriorly a depression corresponding to the situation of the posterior half of the glenoid cavity is observable: into this depression the finger can be sunk so far as to reach the surface of the posterior part of the glenoid cavity. When the arm is drawn forwards across the chest, the head of the humerus passes backwards beneath the acromion, and a depression can be felt in front beneath the coracoid process, corresponding to the portion of the abnormal articular cavity which the head of the humerus had just before occupied. The muscles of the region of the shoulder are very imperfectly developed, but those of the fore-arm and

Fig. 441.

Case of M. H. — Congenital malformation of the left shoulder joint, with luxation of the head of the humerus inwards.

hand seem of their normal size. The patient has but little power of moving the affected upper extremity. The trapezius muscle of this side is well formed, therefore he can by means of its influence elevate on the side of the trunk the whole limb. The deltoid and capsular muscles are very imperfectly formed, and consequently the patient has no power of abduction, nor of rotation, of the humerus. The shoulder has not the usual rounded form, but still it does not present the flattened appearance, nor the acromion the angular outline which characterises the accidental luxation of this joint. Yet the acromion process does project somewhat, and when the arm hangs by the side, the head of the humerus, distinct and prominent, is removed so much from the under surface of the acromion, as it were by the weight of the limb, that the thumb can be easily placed between them. When we take hold of the elbow and raise the arm vertically, the joint assumes more of a natural form. Still, independent of its comparative diminution of size, it wants the rotundity and fulness of contour ordinarily derived from a proper development of muscular covering. The elbow joint is perfect as to its form and functions. This patient has been under the writer's observation for many years, and these symptoms have not varied.

Anatomical characters of congenital malformation of the shoulder joint with displacement of the head of the humerus inwards. — We may consider the following as a good example, showing the anatomical characters of the congenital malformation of the shoulder joint, *with displacement inwards* of the head of the humerus; the congenital defect existed in both shoulder joints.

Case.—" A female, ætat 28, who had been for many years a patient in the lunatic department of the House of Industry, died of chronic in-

flammation of the membranes of the brain, and Dr. Smith* made the post-mortem examination. Upon entering the room his attention was attracted by the appearances which the shoulder joints presented. The deviations from the normal state were most remarkable at the left side. The muscles of the shoulder and arm were atrophied, the acromion process projected considerably, and the head of the humerus could be perceived lying a little beneath the coracoid process, the apex of which was in a line with the bicipital groove of the humerus. The natural roundness of the shoulder did not exist, and the elbow could be readily brought into contact with the side. The right shoulder joint presented similar appearances, but in a slighter degree; the head of the humerus was not placed so directly beneath the coracoid process; but the flattened form of the shoulder, the atrophied muscles, and the projection of the acromion, all indicated that the condition of the joint was nearly similar on both sides. From the last circumstance, and the absence of any external sign of disease, it was concluded that the deformities were the result of an original or congenital malformation.

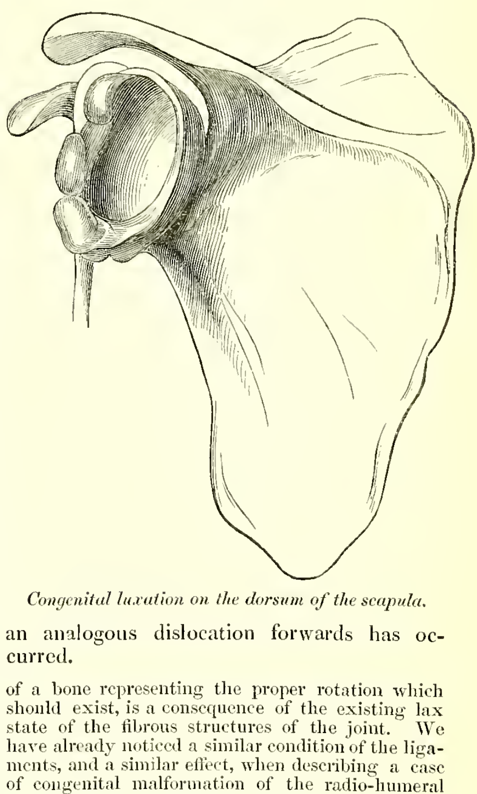
The *anatomical examination* of the joints confirmed this opinion. Upon the left side there existed scarcely any trace of an articular surface in the situation which the glenoid cavity occupies in the normal state; but there had been formed on the costal surface of the scapula a socket of a *glenoid* shape, measuring an inch and half in its vertical direction, and an inch and a quarter transversely. It reached upwards to the under surface of the coracoid process, from which the head of the humerus was merely separated by the capsular ligament, there being no interval between the summit of the abnormal socket and the coracoid process. Around this socket the *glenoid ligament, perfect* in every respect, was continued from the margin of that small portion of the natural articulating surface which existed upon the axillary margin of the bone, and to the apex of which the tendon of the biceps was attached. The capsular ligament was perfect. The head of the humerus did not present its natural spherical form; it was of an oval shape, its long axis corresponding with that of the long axis of the shaft of the bone. The shaft of the humerus was small and seemingly atrophied, and the position of the bone with respect to the coracoid and acromion processes varied according as the motion of rotation inwards or outwards was imparted to the arm. During rotation outwards in this case the head of the bone passed towards the acromion process, and occupied the small portion that existed of the glenoid cavity on the normal site; while rotation inwards brought the head of the humerus altogether beneath the coracoid process, so that the finger could be easily sunk into the outer portion of the socket.†

On the right side, although the condition of the bones was somewhat different, the characteristic features of the deformity were similar.

In this case it was ascertained, that there never had been any disease of either of the shoulder joints at any period of the patient's life, nor had they ever been the subject of injury or accident of any description. The position of the glenoid cavity in this case, beneath the coracoid process, the remarkable form of the head of the humerus, the presence of a perfect glenoid ligament, the absence of any trace of disease, and the existence of the deformity upon each side, all indicate that the nature of the malformation must have been congenital, although but little of the early history of the case was known.

Congenital malformation of the shoulder joint, with displacement of the head of the humerus on the dorsum of the scapula. — The second case we think right to abstract from Dr. R. Smith's work is also a very important one, equally proving that a double congenital luxation of the head of the humerus may be observed to take place backwards on the dorsum of the scapula, just as we have already shown that an analogous dislocation forwards has occurred.

Fig. 442.



Congenital luxation on the dorsum of the scapula.

* Smith on Fractures, &c.

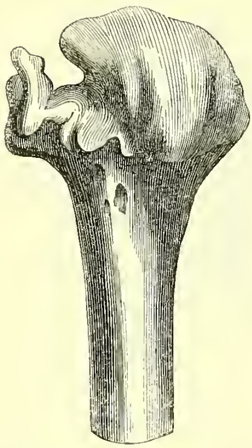
† This species of locomotion of the articular head of a bone representing the proper rotation which should exist, is a consequence of the existing lax state of the fibrous structures of the joint. We have already noticed a similar condition of the ligaments, and a similar effect, when describing a case of congenital malformation of the radio-humeral joint. See Elbow Joint, Vol. II. note to page 81, where it is said — "These movements did not consist in a simple rotation of the radius on its longitudinal axis, but a real change of the upper extremity of the radius on the outer condyle of the humerus."

Case. — A woman, named Judith Doyle, died upon the 8th of February, 1839: she had been a patient for fifteen years in the lunatic department of the House of Industry; was subject to severe epileptic convulsions, which were the cause of her death. While making the examination of the brain, the unusual appearance which the left shoulder joint presented accidentally attracted the author's attention. The head of the humerus appeared to have been dislocated on the dorsum of the scapula. Finding that the opposite shoulder presented precisely similar appearances, he had no hesitation in expressing his opinion that the case was one of double congenital luxation of the head of the humerus backwards.

The two shoulders resembled each other so perfectly, not only in their external conformation, but likewise in their anatomical characters, that the description of one will be sufficient.

The coracoid process, owing to the removal of the head of the humerus from its vicinity, formed a most remarkable projection, and the subject being emaciated, the coraco-brachialis and the short head of the biceps could be seen passing very obliquely downwards and outwards, and the anterior margin of the coraco-acromial ligament stood out in strong relief. The acromion process was unusually prominent, although it did not project as much as in any of the accidental dislocations of the shoulder. The glenoid cavity could not be felt, although the head of the humerus was so far removed from its natural position. The shoulder appeared higher than natural, and was flattened anteriorly; but posteriorly a round, solid tumour plainly indicated the situation of the head of the bone placed on the dorsal surface of the scapula, immediately below the spine and posterior angle of the acromion. The head of the bone thus displaced could be seen and felt to accompany all the movements given to the shaft of the humerus. The transverse diameter of the shoulder was much greater than natural, the distance between the coracoid process and the external surface of the head of the humerus being three inches and a half; the arm was directed obliquely downwards and inwards; the elbow was in contact with the side, and the hand and fore-arm in a state of pronation. Upon removing the muscles and exposing the interior of the joint, I found that there was no trace of a glenoid cavity in the natural situation; but upon the posterior surface of the neck of the scapula there was a well-formed socket, which received the head of the humerus. It was an inch and three quarters in length, and one inch in breadth; it was a little broader above than below, and its summit was less than a quarter of an inch from the under surface of the acromion process. It was directed outwards and forwards, was covered with cartilage, and surrounded by a perfect glenoid ligament. The tendon of the biceps muscle arose from the most internal part of its superior extremity, from whence it passed downwards and outwards very obliquely, in order to reach the bicipital groove of the humerus.

Fig. 443.



Congenital malformation of the left humerus.

The axillary margin of the scapula, if prolonged upwards, would have passed nearly altogether internal to the abnormal socket. The surfaces of the acromion process had not their normal aspects, but looked directly upwards and downwards, being on the same continuous plane with the surfaces of the spine of the scapula that contribute to form supra- and infra-spinatus fossa; a circumstance in itself sufficiently showing that the malformation was congenital, and not altogether limited to the shoulder joint itself. The capsular ligament was perfect; the scapula was smaller than natural, and its muscles badly developed. The head of the humerus was of an oval form on the right side, somewhat broader above than below; its anterior half was in contact with the glenoid cavity: this portion was covered with cartilage, the remaining half being rough and scabrous, and destitute of articular cartilage. The greater tubercle was normal as to form, but the lesser was elongated for the extent of one inch, and curved upwards, forming a concavity on its upper surface to receive the tendon of the biceps; on the left side, the head of the humerus presented almost similar appearances. The hypertrophy of the lesser tuberosity, Mr. Smith observes, appears to have been the result of a process established to counteract the danger to which the very oblique course of the tendon, with regard to the muscular fibres, exposed it.

The history of this case, so far as the motions which the head of the humerus was capable of performing, is not known; but we may conclude from the post-mortem examination, that there was here a complete congenital dislocation on the dorsum of the scapula. A well-formed socket existed on the dorsum of the scapula, upon which the head of the humerus was permanently lodged; it did not shift its position during the motions of

rotation, as was mentioned to be the case in the former example.

We must agree with the author that the phenomena noticed in this rare and remarkable case originated neither in disease, nor were they the result of accident. The complete absence of a glenoid cavity in the normal situation for it, the existence of the malformation on both sides, the perfect resemblance to each other of the abnormal sockets, in form, size, and position, the integrity of the tendon of the biceps and of the capsular and glenoid ligaments, and the peculiar form of the head of the humerus, as well as of the acromion process of the scapula on each side, all support the opinion that the malformation was intra-uterine and congenital.

(*Robert Adams.*)

SIXTH PAIR OF NERVES. *Le Sixième Nerf*, Fr. ; *Sechster Nerv*, Germ. According to the enumeration of Willis, this name is bestowed upon a single soft round cord, which is, with the exception of the fourth, the smallest of the cranial nerves, and which, passing forwards from the medulla oblongata to the external rectus of the eye, finds its distribution in this muscle.

The anatomy of this nerve is readily subdivided into three portions. The first of these extends from its apparent origin to the point where it enters the cavernous sinus; the second includes its course in that cavity ; and the third, commencing at the sphenoidal fissure or foramen lacerum anticus, contains the course of the nerve in the orbit, and is terminated by its distribution.

The visible *origin* of the nerve is by one or two bundles from the medulla oblongata, from the anterior pyramid of which it appears at its upper part, or in the transverse depression immediately behind the posterior border of the pons varolii. By careful dissection, the nerve can be traced into the substance of this anterior column, and, apparently, it passes through it towards the grey matter which more deeply surrounds this tract of the medulla. Further than this it is impossible to follow it satisfactorily, although some anatomists have, with Mayo, assigned to it a yet deeper origin. In the *first* part of its course the nerve passes forwards, upwards, and outwards for a very short distance, from near the median line to the posterior extremity of the cavernous sinus which forms the commencement of the inferior petrosal sinus. In this course it lies upon the concave basilar surface of the sphenoid bone, and is covered above by the projecting pons varolii ; and at the front, where it leaves the interior of the skull, the arachnoid membrane is reflected around it. It next passes through an opening in the dura mater, and enters the cavity of the sinus. This aperture is situated just internal to the tip of the petrous bone, and is about one-third of an inch anterior to the orifice of the fifth nerve, bnt on a rather lower level.

On entering the sinus, it is somewhat curved or bent into a more horizontal direction, and crosses over the posterior or vertical part of the carotid artery, which here experiences its sigmoid bend by the side of the body of the sphenoid bone. It next lies parallel to, but beneath, the horizontal part of this vessel, and passes almost directly forwards, through and amongst the numerous reticulations which occupy the cavity of the sinus, but it is covered by its lining membrane. At the anterior extremity of the cavernous sinus it enters the orbit by passing between the two heads or processes of origin of the external rectus muscle.

Since the nerve in this course lies within the sinus, it is internal to the three nerves, viz. the third, fonrth, and the ophthalmic division of the fifth, which are situated in the dura mater forming its outer wall. Posteriorly, the lowest of these, or the ophthalmic nerve, lies on much the same level, but nearer to the sphenoidal fissure. The latter nerve having passed upwards, the sixth is left again occupying the most inferior and internal position of all the nerves which pass through this orifice, the lower division of the third being to its inner side, and somewhat superior to it, whilst above this is the nasal branch of the fifth. Below the sixth nerve, the ophthalmic vein perforates the dura mater of the sinus by a separate aperture,

In the cavernous sinus, the following branches are connected with, or come from, this nerve : —

1. It is connected with the *sympathetic* nerve by several filaments. Two of these are of considerable size, and may be traced backwards at rather an acute angle from the trunk of the nerve, to join those numerous ramifications of the sympathetic which constitute the carotid plexus surrounding the artery in this venous cavity.

2. An anastomosis, or junction with the ophthalmic branch of the fifth, is described by most anatomists, and may be readily verified in the recent subject. One or more branches, having very much the same direction and appearance with the preceding to the sympathetic, pass backwards from the sixth nerve, in the anterior part of the sinus ; leaving it at a very acute angle, inclining outwards as they go, and finally, entering the wall of the sinus to join the ophthalmic branch, not far from the Gasserian ganglion. These branches also exist in the sheep, and some other of the lower animals.*

* A very similar description might be extended to the analogous junction of the fourth nerve with this division of the fifth. Thus, in the sheep, three or even four considerable branches leave the ophthalmic nerve at an acute angle to join the fourth nerve. They effect this junction very obliquely, and may be traced forwards (distad) for at least some distance. May not some of these filaments, traced backwards from the fourth nerve to the wall of the cavernous sinus, which they enter to join the ophthalmic division, have been the *tentorial* branches of Bidder, which he describes as coming from the former nerve to be distributed to the dura mater of the tentorium?

3. A very fine filament from the sixth nerve to the ciliary or lenticular ganglion has been described by several authors.

Subsequently to the cavernous sinus, the course of the nerve is but short. Arriving at the posterior extremity, or apex of the orbit, the nerve lying to the outer side of that part of the third which supplies the inferior rectus and oblique muscles, runs slightly upwards, and turning outwards, continues for a very short distance along the inner surface of the external rectus. It finally breaks up into numerous minute filaments, which enter the ocular surface of this muscle to be distributed to it.

Physiology of the sixth nerve.—The function of the nerve is, perhaps, sufficiently indicated by the preceding details. Since *anatomy* shows that its terminal distribution is exclusively to a muscular surface, we should on this ground alone be tolerably entitled to predicate its motor function.

The little that is known of its *comparative anatomy* confirms the inference. In all the higher vertebrata it is distributed to the external rectus. In some, however, it experiences an enlargement, and a further distribution. The muscle which sweeps the broad nictitating membrane over the bird's eye, and the funnel-shaped, or choanoid muscle which surrounds the optic nerve and eyeball of many mammalia, are both supplied from this nerve.

So also one or two cases are recorded, in which an injury of this nerve from *disease* in the neighbourhood has produced paralysis of the external rectus, and an inward squint. While, *vice versâ*, the experiment of galvanising the nerve has been accompanied by violent contractions of the muscle, and an external strabismus.

The insensibility of the nerve is, perhaps, less certain than might at first appear, though Longet * distinctly states that pinching the nerve at its origin is unattended by signs of pain. The branch of junction with the ophthalmic nerve seems to be, from its direction and appearances, much more like a filament from the sensitive to the motor nerve, than from the latter to the former. If this be the case, they would seem to be somewhat analogous to the junction of the numerous branches of the fifth with the portio dura on the face. And in the absence of direct experiment upon the nerve beyond the seat of this union, one might conjecture it as possible, that the sixth nerve was possessed of a slight sensibility similar to that of this portion of the seventh. Concerning the import of the junction with the sympathetic, little can here be said; for although, as compared with the size of the communicating nerves, this union is larger than most others, yet there does not seem any sufficient reason for supposing other differences.

The distribution of a branch from the sixth to the ciliary ganglion has been thought by Longet and others to explain the persistence of movements of the iris after paralysis of the third nerve. But besides that the constant existence of this filament seems hardly verified; perhaps the interposition of a ganglion between the paralysed nerve and the ciliary filaments might alone be thought a sufficient explanation of the inconstancy or imperfection of the result, without requiring the existence of another and an uninjured channel as the cause.

Bibliography.—See "NERVE."

(*William Brinton.*)

* Sur le Système Nerveux.

SKELETON. — The name skeleton, σχελετον, formed from σχελλω, *to dry*, is, in anatomy, ordinarily applied to denote that assemblage and arrangement of all the osseous pieces of an animal framework in such connection and relationary order as the hand of nature has disposed them for fitting operation in the living body.

The less the name skeleton impresses the mind with the configuration of any particular form of the osseous machines, the better is it fitted as an abstract general title, under which to give a comparative survey of all figures of the osseous system, whatever be their special characteristics; and this abstract survey being my present purpose, I find that the name skeleton, devoid as it is of any direct and inconvertible meaning, conveniently extends itself over all varieties of the osseous fabrics of the four higher classes of animals; from the mutual comparison of which I shall strive to elicit the law which creates them in the character of a *unity in variety* *, a condition of form by which the many species gather themselves together naturally into a circle and point to some unknown oneness of character which enchains them the one to the other.

This law of *unity in variety* is still uninterpreted; and though it formed the moving theme of the great Grecian naturalist † three thousand years back, and afterwards lay in cold obstruction till resumed in later times by Leibnitz, Newton, Buffon, Cuvier, Geoffroy St. Hilaire, Oken, Göethe, Carus, Owen ‡,

* Leibnitz makes use of this phrase as being the general expression of his ideas of that condition of development manifested throughout the animal kingdom, namely the condition of an all-encompassing structural analogy which relates organised beings more or less closely to one another. His "loi de continuité" is founded likewise upon the same general fact. He defines the universe as "l'unité dans la variété," and of the animal kingdom he writes, "tout va par dégrés dans la nature, et rien par saut." See Œuvres Philosophiques de M. de Leibnits, liv. p. 440.

† Aristotle, the great founder of generalisation in the physical sciences, was strongly impressed with the common resemblances or analogies of animals, and expresses the fact as follows: — "But some animals neither have parts specifically the same, nor the same according to excess and defect, but according to analogy." History of Animals, book i. p. 4. trans. by Taylor.

‡ The late work of the learned Hunterian professor, entitled "Homologies of the Vertebrate Skeleton," contains, in addition to his own especial views, a complete account of all that has been written upon the subject of skeletal analogies by the leading com-

Grant, and others, still does it remain as an open arena of inquiry, courting the votary of truth to enter there and allure her from her secret covert. All that has been written has not fixed the Protean interpretation of this law which governs the developement of vertebrated skeletons. Since, therefore, this theme (upon which so many great inquirers have assayed interpretations which conflict with each other, and in the struggle lose the clue of truth), even to this hour fails of the culminating idea, and is by so much imperfect, of what avail would it be to the reader or myself were I to discuss the merits of the various opinions such as they stand? Rather than dispute about opinions, I shall turn to the facts themselves, upon which those opinions have been grounded, and engage at once in the comparison of facts as facts independent of all opinion respecting them, and unmindful of the names * by which they are liable to be mistaken for what they are not.

Under the abstract term skeleton, I shall take a general survey of the whole subject of comparative osteology; and if the reader chooses to call this survey "transcendental," I shall endeavour to show that it shall not be visionary. My argument shall set out from a first proposition, through a successional enchainment of propositions; and in the matter of all the propositions taken collectively, I shall body forth an interpretation hitherto unknown in anatomical science. The facts and their proper interpretation may be fairly termed the body and soul of truth, and such a truth is a compound of the actual and the intellectual. The facts themselves give evidence to all observers of the truth of "unity in variety," but it is by inductive reasoning that the intellect is to interpret the law, the potential agency, by which the same facts are at the same time uniform and yet various.

The object which I shall keep in view while constructing my comparisons, is to demonstrate the figure of unity, and give interpretation to the figures of variety which are sprung of it. To this end I shall prove,—

1st. That all the osseous skeletal forms are quantitatively unequal things.

2d. That they are the unequal quantities of a greater or archetypal form *, a unity which has undergone such an infinitely graduated metamorphosis of its parts as to yield these unequal skeletal forms.

3d. That the law of formation is one of degradation of an archetypal uniform original.

4th. That these unequal skeletal forms constitute the species or varieties of the unity of the archetype.

5th. That the whole or archetypal form of which these unequal skeletal figures are the parts, is the only absolutely uniform skeletal series.

6th. That nomenclature and all modes of classification, according to specific distinctnesses, have no real meaning apart from the consideration of this law of an archetypal uniform prime model undergoing a graduated metamorphosis of its parts. That in this higher law of graduated series is enveloped all lesser laws of classes, orders, genera, species, and individuals, which, whatever be the amount of their distinctive characters, do one and all point to a unity of type more or less.

With this purpose before the reader's mind, I proceed to lay down my propositions as preliminaries by which to pioneer a passage through the blinding thicket of nomenclature and gain the light beyond it, the light of a general law † in nature. But before he

parative anatomists of the German and French schools. To this work, and the principle which the author endeavours to establish, I shall frequently refer; and believing (as all who shall study that work must believe) that the meritorious object of its distinguished author is to give creation to a great truth in science, at the same time that he is not unwilling to give ear to all counter-argument rationally advanced, I shall therefore not hesitate to question the principle set forward in the work, as freely as shall serve my own purpose, which holds the like object in view. In whatever points, therefore, I may take objection to the author's reading, and in doing so may appear too rash to question so great and philosophical an authority, it is the cause which must be my excuse.

* "This, if we rightly consider and *confine not our thoughts and abstract ideas to names*, as if there were or could be no other sorts of things than what known names had already determined and, as it were, set out, we should *think of things* with greater freedom and less confusion than perhaps we do." Locke, Reality of Knowledge.

* This term, *archetype*, having been first introduced by me in the study of comparative osteology, may require here a word in explanation. When I first applied myself to the study of the law of "unity in variety" which presides over the development of vertebrated skeletons, there appeared to be such a shadowy and ill-defined meaning in the term unity in variety, and the facts of form themselves presented in such a mysterious condition of enchained analogous characters, and at the same time gave such unmistakeable evidences of an enchained specific diversity, the latter encountering the former condition at every step of inquiry, and neither the differences nor the analogies (while contemplated as such under the same regard) holding forth to me any promise of an end to labour and research, that I at length resolved to know (in addition to the self-evident analogy which the facts manifested) whether or not the deferential properties were mainly owing to some law which degraded or proportioned the lesser and special forms from some greater or whole form—some integer or full skeletal figure which might be seen as containing in its own quantitative character the sum of all known varieties or species. The comparative method which I adopted to define the existence of such a figure realised my expectation, as I shall presently show, and to this figure I gave the name *archetype*.

In a paper "On Anatomical Nomenclature," addressed to Professors Owen and Grant, published in a number of the Lancet, March, 14. 1846, I have spoken of the figure of an archetype skeleton.

About the same time that I since published my work on "Comparative Osteology aud the Archetype Skeleton," bearing date 1847, I felt gratified to see that the learned Professor Owen sanctioned the name archetype, and gave it the weight and interest of his philosophical researches. See his work, entitled "The Archetype and Homologies of the Vertebrate Skeleton," published 1848, being a second edition of his work bearing the same title, published 1847.

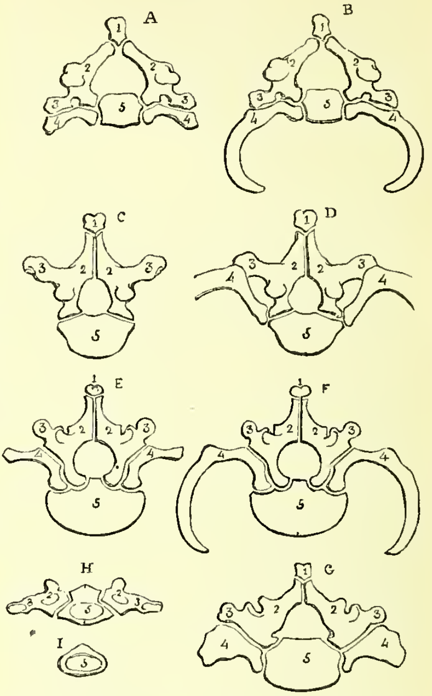
† "Les lois, dans la signification la plus étendue, sont les rapports nécessaires qui dérivent de la

passes with me to my task of comparison, I warn him that he should feel within himself a full conviction of the truth, that in order to gain a fair insight of the law of formation, he must not suffer names of different significations to hide the common analogy or similitude which the things themselves manifest. He must have fully freed himself of the barbarisms of the nomenclature which the unreasoning human anatomist still makes use of; he must not suppose that because one spinal piece is named sacrum, it is therefore absolutely different to another spinal piece named vertebra. And even in respect to the name vertebra *, which applies alike to all spinal segments, however quantitatively different these may be, he should not think these the same things in form and dimensions, and elemental constituents, simply because they bear the same name.

For in reality this name vertebra attaches to bodies which are quantitatively different, and is, therefore, a name as truly misapplied to generalise not only over the spinal units of the skeletal axes of the four classes of vertebrata, but even over those of the human type; as if, while viewing a series of circles, semicircles, and segments, we called it a series of segments of semicircles or of circles, which it evidently is not. We would not call the two quantities, viz. circle and segment, by the same name; neither should we name such different quantities as cervical, dorsal, and coccygeal forms under the common title "vertebræ." If we fully ackowledge to this first truth, truth will be begotten of it; but if we still begin the calculation with the error, error will spring from out of it, and defy all mathematical computation.

Proposition I. *Vertebræ are unequal quantities.*—In the human spinal axis I find that those bodies which the human anatomist terms vertebræ are not quantitatively similar, equal, or homologous.† The cervical vertebra (A, *fig.* 444.) differs in this respect from the dorsal vertebra (C); this from the lumbar vertebra (E);

Fig. 444.



Vertebræ of the human spine,

Showing a quantitative difference. The similar parts of each bear the same figures.

this from the sacral vertebra (H); and this from the coccygeal vertebra (I). In all animal spinal axes I see that those bodies which the comparative anatomist names vertebræ are likewise quantitatively different. The several classes of vertebræ termed cervical, dorsal, lumbar, sacral, and caudal, are actually developed of unequal quantities. And it is, moreover, most true that even the vertebræ of any one class, whether of the cervical class, the dorsal, lumbar, sacral, or caudal, are not quantitatively similar or equal. In animal cervices, thoraces, or loins, the vertebræ constituting any of those regional divisions of the spinal axis are not equal quantities. Even in

nature des choses." Esprit des Lois, lib. i. ch. 1. Montesquieu.

* Lamarck originated the name *vertebrated*, as characterising one great division of the animal kingdom,—"Les animaux vertèbres," from the other "Les animaux sans vertèbres." But comparative osteology, as studied in the present time, has almost rendered this name obsolete, incapable, as it evidently is, to be the instrument wherewith to generalise the skeletal frameworks of the four classes of animals. Even the originator himself seems to have entertained a doubt as to the efficiency of the name, or any mode of classification, or method, or nomenclature used in subdividing the continuity of the chain of nature. He writes, "Mais j'ai dejà montré qu'il est un produit de l'art, et que malgré les apparences contraires il ne tient réellement rien de la nature." See Philosophie Zoologique, tom. i. chap. v.

† This term "homologous," as used by the geometrician, means *corresponding*. Figures are called similar or corresponding whose sides and angles are homologous. Quantities having the same manner or proportions are homologous. Quantities, therefore, which are not equal to one another are not homologous; but such quantities, though being unequal, may still possess the correspondence which we see apparent in the proportionals of a whole quantity; thus a segment of a circle or a semicircle, though not equal to the circle, manifest a proportional correspondence all three; and in the same way, vertebral quantities which manifest to each other a similar degree of proportional correspondence, seem to point to some unknown whole quantity of which they are the parts. Philosophical anatomists seem to have all agreed upon the point, that the name vertebra attaches to certain osseous forms arranged along the spinal axis, which, in fact, are proportionally diverse bodies, and being so acknowledged, they have directed comparative research to determine the quantitative form of the "typical vertebra." The difficulty of this inquiry into the form and quantitative character of the typical vertebra may be learned from the fact, that science has not, as yet, determined it upon the firm basis of demonstrative evidence.

the human cervix, thorax, or loins, or sacrum, or caudex, the vertebræ of each region manifest those quantitative differences. For we find in the human neck that B, or in the loins F, occasionally develops a surplus rib (*fig.* 444. B and F, 4); which circumstance gives rise to a serious objection to the rule, that "the mammal cervix is constant to the number of seven vertebræ," or that the thorax of even the human skeleton develops twelve vertebræ constantly, or that the human lumbar region is confined to the number of five vertebræ constantly. It is evident, therefore, that the bodies named vertebræ are quantitatively different bodies, as seen not only in all spinal axes comparatively estimated, but even in the one animal spine of human type.

PROP. II. *Even the one vertebra is not of equal quantity in all individuals of the same species.*— Comparative research proves that all vertebræ are quantitatively unequal entities; but this is not all, for even when I fix attention upon the single isolated vertebral segment of the spine, I find that it manifests a fluctuating character as to proportions and elementary quantity. The seventh cervical vertebra (A, *fig.* 444.) of the mammal spinal axis occasionally produces a costal appendage (4 of B). The first lumbar vertebra (E, *fig.* 444.) of the human spine likewise develops now and then the costal appendages (4 of F, *fig.* 444.); and hence it is that anatomists are still undecided whether to name them thoracic vertebræ or not. I do not here intend to discuss those several interpretations which anatomists have advanced concerning the cervical and lumbar ribs, for we should find ourselves in the end as little enlightened about the true nature of the anatomical fact as when we first set out, suffice it here that we fully own to the fact; that the body which we name vertebra is not always equal to itself at all times even in the one fixed locality of the spinal series.

PROP. III. *All vertebræ contain a greater or lesser amount of certain known elemental pieces.*—If we will consider why it is that we designate vertebral bodies under one generalising appellation, we will find that it is on account of vertebræ (whatever be their special variety) containing few or more of those elemental nuclei from which vertebræ are fashioned. Thus as we find vertebræ to be constituted from a whole sum of elementary pieces proper alone to vertebral form, we therefore consent to give the name vertebra to every spinal figure which shall produce any one element proper to the ideal vertebral type. But then we must not understand by this name *vertebrated*, a condition of absolute quantitative uniformity* throughout the bodies so named; for to do so would be as directly opposed to natural evidence as to understand by the name endoskeleton, that all figures so named were absolutely uniform with each other in quantity. The truth is that vertebræ are as much varied to each other as skeletons; but the truth also is that vertebræ are only quantitatively different, just as skeletons are. A coccygeal vertebra (I, *fig.* 444.) is only different from a lumbar (F, E) or cervical vertebra (A, B) by quantity; and a skeleton of a frog is different to that of a whale by the condition of variable quantity also. But a coccygeal vertebra (I, *fig.* 444.) is in reality a vertebral centrum (5) unattended with the presence of those other elementary pieces, such as laminæ marked 2, 2, spinous (1), and transverse processes (3), which elsewhere constitute the completer vertebral form; and hence it is to be inferred that a coccygeal vertebra is a minus quantity, and as such differs in this respect only from a lumbar or cervical vertebra; these latter being plus in those very same elements which the coccygeal vertebra wants. It is sufficient for us at present to know clearly that all vertebræ have some elements in common, and that the only difference which appears between them is occurring by a simple omission of elementary parts from some vertebræ, which parts are present and persistent in other vertebræ. The coccygeal bone (I, *fig.* 444.), being as a vertebral centrum (5) identical with the centra marked 5 in all other vertebra, is different from all other vertebræ simply by the loss of parts; and those parts which it has lost are evidently such parts as I find in a vertebra elsewhere posited, viz. the parts marked 1, 2, 3, 4.

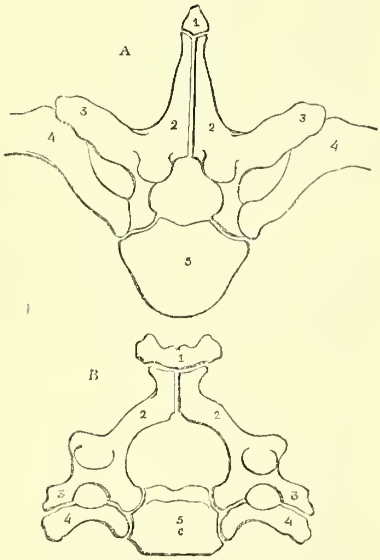
PROP. IV. *The dorsal vertebra of human anatomy is an artificial figure.* — The human anatomist separates the dorsal vertebra (C, *fig.* 444.) from its costal appendages marked 4 in D, *fig.* 444., and by so doing he disconnects forms which nature has created inseparable from each other. In nature there is no such ens as the dorsal vertebra (C, *fig.* 444.) developed without the ribs (4 of D.); nor can we conceive the idea of a dorsal ver-

* The uniformity of a serial line of bodies implies that all units of the line of serial order are quantitatively equal and homologous. A series of circles would constitute such an uniformity, because all such circles would be similar. Uniformity, taken in this sense of equality among the units of the series, does not characterise the vertebral spinal series; but while we see that vertebræ, though not uniform as quantities, are still various only as proportionals of a greater ens or archetype, then the question arises as to how these proportionals have had creation? It is evident that the solution of this question is attainable only by a rule of equation, which, while it acknowledges the condition of the proportional, or the $a-b$, must fill up or supply mentally (without deference to the doctrine of functional fitness) the differential quantity which is to equate it with $a+b$; and this is the mode which I adopt, in order to re-establish the original typical uniformity of skeleton bodies, for I shall prove that the known quantitative difference between two unequal forms renders them equal in idea. The typical skeleton of Carus and Owen is an ideal creation, sprung from a rule of comparison which rejects (as I mean to do) the teleological doctrine of Cuvier, and undertakes to compare form as form, regardless of the difference as to function. The paramount necessity of this will at once occur to the reader, and he will recognise in the truly philosophical researches of the Hunterian professor an advance towards the truthful interpretation of the law of formation, equal in degree to the measure of this mode of comparison adopted by him.

tebra naturally independent of its costa.* When we bisect the circles we make semicircles; but by so doing we cannot possibly lose sight of the fact, that both semicircles once constituted the whole circle; and in the same way, when we separate the dorsal vertebra (C) from its attendant ribs (4 in D), we cannot obliterate from the memory the idea, that the dorsal vertebra and its ribs once formed an entire osseous quantity as that represented by D, having the ribs appended. When the human anatomist separates the dorsal quantity (C, *fig.* 444.) from the costal elements 4 in D, and describes the quantity of C as a vertebral figure, he commits an error no less visibly opposed to natural evidence than if he separated one half of the dorsal element from the other half, and called either half a vertebra. The dorsal vertebra (C) of human anatomy is therefore inseparable from its thoracic ribs (4 of D), and to these several pieces naturally combined and collectively contemplated (in D), I give the name *costo-vertebral quantity*.

PROP. V. *The cervical vertebra develops the costal appendages also.*—In order to prove incontestably that the anterior moiety (4) of the

Fig. 445.



A, dorsal vertebra ; B, cervical.

transverse process (4, 3, *fig.* 445. B), is the true homologue of the thoracic rib (4, *fig.* 445. A), I shall lay down my remarks as follow:—I separate from the human spinal axis that body (C, *fig.* 444.) which the human anatomist terms the "dorsal vertebra;" and on comparing it with the cervical vertebra (A, *fig.* 444.), I find that both figures are identical as to the number and position of their elemental pieces in all respects save one particular. This one point in which the cervical vertebra (A, *fig.* 444.) differs from the dorsal vertebra is evidently the anterior moiety (4) of the transverse process of the cervical vertebra (A); for the dorsal vertebra (C), such as the human anatomist describes it, does not contain any elemental piece as the true counterpart or homologue of the element (4) which is posited as the anterior half of the cervical transverse process.* In both vertebræ (A, C, *fig.* 444.), I find the spinous elements marked 1, the laminæ or neural arches (2), and the bodies or centra (5); but it is attaching to the transverse processes of both vertebræ that a doubt arises as to their identity. Now if I call the posterior moiety (3) of the transverse process of *fig.* 445. B, the true homologue or counterpart of the dorsal transverse process (*fig.* 444. C, 3), I still have no element in the dorsal vertebra (*fig.* 444. C), wherewith to compare the anterior half (4) of the cervical transverse process of *fig.* 445. B. But when I apply the costal piece (4, *fig.* 445. A) to the dorsal vertebra, constituted of the pieces 1, 2, 3, 5, then it becomes evident that this costa is supplying the place of the anterior half (4) of the cervical transverse process (*fig.* 445.).

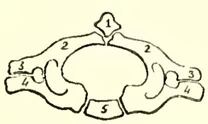
* I call the reader's attention particularly to this fact, as a starting point from which I set out with my argument, which is to conduct to the recognition of what I call *whole quantities* in the skeleton axis. It will be seen afterwards, that owing to this first error of the anthropotomist arbitrarily severing the ribs from the dorsal spinal centre, and giving to this latter the name vertebra, much confusion has arisen in the comparative method and its inferences. "Errores radicales et in primâ digestione mentis ab excellentiâ functionum et remediorum sequentium non curantur." Novum Organon Scientiarum, Aph. 30.

* All anatomists (the comparative as well as the human) had, until lately, overlooked the compound nature of the transverse process of the cervical vertebra; and even when this character of the process came to be fully acknowledged, still so difficult was it for them to emancipate themselves from the toils of the original error committed by the anthropotomist, that we find them more willing to bend the stubborn facts of nature in accordance with the error, than to correct the oversight. Thus, agreeably with the artificial vertebral quantity of the human anatomist's "dorsal vertebra," whose transverse process is single, that of the cervical vertebra being double, both processes were held to correspond nevertheless; and consequently, when such a fact as that of the anterior nucleus of the cervical transverse process being produced to the dimension of a cervical rib appeared, they, with Meckel, interpreted this as a prolongation of the cervical transverse process, which they had already regarded as homologous with the process so named in the dorsal vertebra: or with Blainville, they acknowledged its costal character and proportions, but interpreted it as belonging to a "category of ribs proper to themselves," distinct from those of the thorax, and also diverse to those called "cervical ribs" in other classes of animals. And although it had been broadly asserted, long since, by Hunauld, Sandifort, and others, that the transcendental law gave to even the human skeleton more than twelve pairs of ribs—the supernumerary ones which now and then stood upon the cervical and lumbar vertebræ—still, owing to the obstructiveness of the pre-conceived doctrine of the mammal cervix being accounted limited to the number of seven ribless vertebræ, even nature herself failed to prove the invalidity of that general rule, though she presented them with the sloth's cervix, which produces nine vertebræ, and that of the human species occasionally producing only five or six.

And it cannot be doubted, for a moment, that both these elemental pieces, marked 4 in both figures, are identical; for many facts go to prove it: first, both elements marked 4 are posited in the same situation with respect to the other pieces (3, 2, 1, 5) of the vertebræ; second, both are "*autogenous*," that is to say, they are developed as separate and isolated deposits; third, they hold the same serial order in the spinal axis; fourth, the anterior element (4) of the cervical transverse process (*fig.* 445. B), is that which is occasionally converted into a rib, as seen in B, *fig.* 444., and thereby simulating more closely the thoracic rib (4) of the dorsal vertebra (*fig.* 445. A.); fifth, a negative evidence may be adduced to prove that the anterior half (4) of the cervical transverse process of *fig.* 445. B, is the true counterpart of the thoracic rib (*fig.* 444. B, 4); for the more clearly it can be shown that the posterior half (3) of the cervical transverse process of *fig.* 445. B, is the homologue of the dorsal transverse process (*fig.* 444. C, 3), the more evident must it appear that neither one or the other of these last-named pieces are homologous to either of the two former; sixth, the posterior half (3) of the cervical transverse process (*fig.* 445. B) and the dorsal transverse process (*fig.* 444. C, 3) are "*exogenous*" growths; that is to say, they are produced of elemental nuclei common to them and the "neural" * or laminar arches marked 2; and therefore it appears that the cervical vertebra (*fig.* 445. B) possesses a costal element (4), just as the dorsal vertebra (*fig.* 445. A) does, the only difference between these vertebræ being, that the costa of the latter is produced of greater dimensions than the costa of the former.

PROP. VI. *All the cervical vertebræ develop costal appendages.* — The identity which has been proved to exist between the seventh cervical vertebra and the first thoracic costo-vertebral quantity will allow it to be inferred, that all the cervical vertebræ, the atlas not excepted, which are fashioned of an equal number of elemental nuclei, must therefore be identical with all the thoracic costo-vertebral quantities. The only difference which exists between the cervical vertebræ, even that named atlas (*fig.* 446.), and the thoracic costo-vertebral quantities (*fig.* 444.) is one of quantity; and this difference in quantity appears upon comparison to be alone attaching to the costal

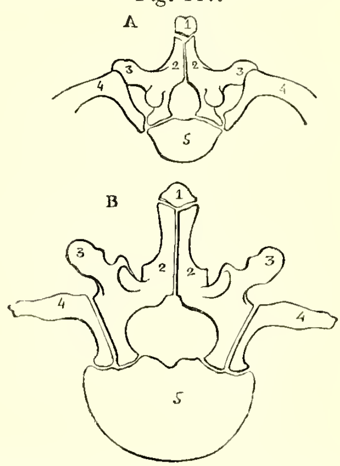
Fig. 446.



appendages marked 4. — The thoracic costæ are of larger dimensions than the cervical costæ.

PROP. VII. *The lumbar vertebra develops the costal appendage.*—When I take the dorsal vertebra (C, *fig.* 444.) (of human anatomy) separated from its costæ, and hold it in comparison with the lumbar vertebra (E, *fig.* 444.), I find that the elemental nuclei of both are, for the most part, equal in number and similar in position and shape. The points by which anatomists doubt their absolute identity are the processes (3 of C and 4 of E), named "transverse" in both, and the process (3 of E) named "tubercle" in the lumbar form. The cause of this doubt I find to be occasioned by an error as to the identity of elementary nuclei, and a consequent misapplication of terms. The cause of the anatomical error originates with human anatomy having described as a complete dorsal vertebra that figure (C, *fig.* 444.) which has never been seen separate from its ribs, as it appears in D, *fig.* 444. The best mode, therefore, whereby we may correct this error, is to take nature as she presents to us, and interpret her by her own evidence, not through the artificial system of any human invention. While I compare the first lumbar vertebra (B, *fig.* 447.) with the last costo-vertebral thoracic form (A, *fig.* 447.), I discover that nature has developed them of the same elemental pieces. In both the spinous element (1), the neural or laminar elements (2), and the bodies or centra (5), are apparent. In both are to be traced the true transverse processes which are homologous to each other in every respect, I mean the process named "tubercle" (3) of the lumbar vertebra (B), and the process named "transverse" (3) of the thoracic figure (A). Both these processes are identical in form, mode of growth, relative position in regard to the other vertebral elements (1, 2, 4, 5), and in serial order with regard to each other. They are the true transverse processes by every anatomical proof, for they are produced of elemental pieces common to them

Fig. 447.



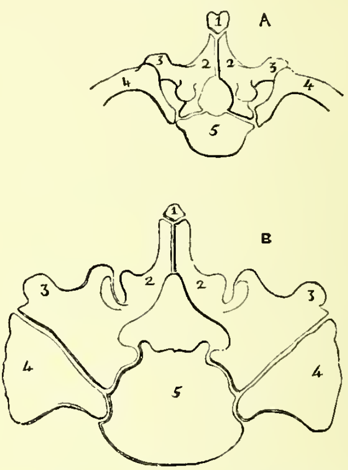
* This term, "neural arch," is used by Professor Owen, from whom the term originates. "By "neural arch, I mean both neurapophysis and neural spine, or the totality of the distinct parts of which such arch is composed." Homologies of the Vertebrate Skeleton, p. 190.

and the neural arches (2).—They are "exogenous." Now the thoracic rib (4 of A) is also the true homologue of the lumbar misnamed and mistaken "transverse" process (4 of B), for both these structures are identical in every respect: 1st, they hold the same serial order; 2d, they are posited in the same situation with respect to the other vertebral elements; 3d, they are autogenous; 4th, the so called "transverse process" (4) of the lumbar vertebra (B) is that very structure which occasionally presents to us in articular costal form and function as seen in 4 of F, *fig.* 444., thereby more closely becoming assimilated to the thoracic rib of the dorsal vertebra; 5th, by negative evidence it may be shown that the thoracic rib (4 of A) is the true homologue of the so named transverse process (4) of the lumbar vertebra (B), for while it stands manifest that the "tubercle" (3) * of the latter is counterpart of the transverse process (3) of the dorsal vertebra, then it must follow that the thoracic rib and the lumbar "transverse process" † so called are also counterparts. The lumbar vertebra therefore produces the costal appendage.‡

PROP. VIII. *All the lumbar vertebræ develop costal appendages.* — That which is true of the first lumbar vertebra and the last costo-vertebral thoracic form must be true of the five lumbar vertebræ and the twelve thoracic costo-vertebral forms, for all the lumbar vertebræ are fashioned of an equal number of elementary pieces. The difference which exists between lumbar vertebræ and thoracic costo-vertebral forms is one of quantity, and the costal appendages of both are those which show this quantitative difference. — The ribs of the thorax are proportionably larger than those of the loins. In the thorax the costæ (4 of A, *fig.* 447.) appear articularly connected with the centrum (5). In the loins the costæ (4 of B, *fig.* 447.) are fixed or anchylosed to the vertebral centrum (5); but this state of anchylosis is by no means constant; and when they articulate freely with the centra of the lumbar vertebræ, then the elements (4) are as ribs seen in F, *fig.* 444.

PROP. IX. *The sacral vertebræ develop costal appendages.*—If it can be demonstrated that the first sacral vertebra is developed of nuclei equal in number, and identical in situation, in form, and in mode of growth with those which are proper to lumbar vertebræ, then we may account both lumbar and sacral vertebræ as homologous with the costo-vertebral thoracic form. And it does appear that the sacral vertebra (B, *fig.* 448.) is actually fashioned

Fig. 448.



of the same number of elements. For the serial order of nucleary deposition throughout the whole length of the spinal axis proves that the anterior nucleus (4) of the lateral mass (3, 4) of the sacral vertebra (B) is the true homologue of the so called "transverse process" (4) of the lumbar vertebra (B, *fig.* 447.), and of the costa (4) of the thoracic form (A, *fig.* 448.) and of the anterior half of the cervical transverse process (4, *fig.* 445.). All these pieces hold serial order; all are autogenous growths; all are posited in the same relation with respect to the other vertebral pieces (1, 2, 3, 5) of the cervical, dorsal, and lumbar forms. Now, having once determined the proper identity of the anterior nucleus (4) of the lateral mass (3, 4) of the sacral vertebra (B, *fig.* 448.), it becomes easy to recognise the homological cast and relation of all the other pieces of the sacral vertebra. The posterior half (3) of the lateral mass of the sacral vertebra (B) is the counterpart of the "tubercle" (3) of the lumbar vertebra (B, *fig.* 447.), of the transverse process (3) of the dorsal vertebra (A, *fig.* 448.), and of the posterior half of the transverse process (3) of the cervical vertebra (*fig.* 445.). The spinous process (1), laminæ (2, 2), centrum, or body (5) of the sacral vertebra (B, *fig.* 448.) are evidently identical with the like-named parts of all the other vertebræ correspondingly numbered. It will hence appear that sacral vertebræ do not differ from other vertebræ; and that it is an error as to the identity of the anterior nucleus

* The "tubercle" is, in human anatomy, accounted as a process specially characterising the lumbar vertebra as distinct from the dorsal vertebra, in which latter the tubercle is supposed to have no counterpart.

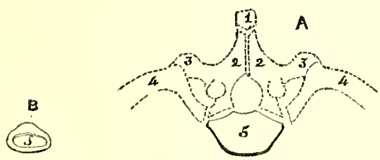
† Cruveilhier states, as a peculiarity of the lumbar transverse process, that it sometimes remains articularly separate, and simulates the costal character, becoming the "supernumerary rib." Meckel alludes to the fact also.

‡ On referring to the "Homologies of the Vertebrate Skeleton," I find the following affirmation: — "Each of the five succeeding segments is represented by the same elements (centrum and neural arch) coalesced, that constitute the so called dorsal vertebra; they are called '*lumbar vertebræ;*' *they have no ossified pleurapophyses.*" Professor Owen's "pleurapophysis" is the rib or costal appendage of his typical vertebra. While he states, therefore, that the lumbar vertebra has no pleurapophysis, he means that it has no rib or costal piece. This oversight (which, with all respect, I believe it to be) has arisen from the evident error of mistaking the lumbar transverse process as being the counterpart or homologue of the dorsal transverse process, which, if such were the case, would leave the lumbar vertebra without a rib.

(4) of the lateral mass of the sacral vertebra (B, *fig.* 448.), which causes the human anatomist to name this anterior nucleary appendage as the "peculiarity" of sacral form. This anterior nucleus of the sacral lateral mass, I call a rudimentary rib abutting against the iliac bone.

Prop. X. *The coccygeal vertebræ are deprived of their costal appendages.* — The serial order in which we find all spinal figures standing, renders it, under comparison, a demonstrable fact, that the coccygeal bones (B, *fig.* 449.) are the debris or metamorphosed

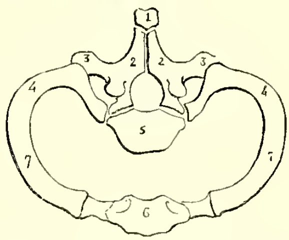
Fig. 449.



remains of true and complete vertebræ, such as A of the thorax. It matters not as an objection to the truth of this idea of coccygeal bones being the minus proportionals of full costo-vertebral quantities, that we now find them wanting many of those elemental pieces which are existing to these latter. For though it be true that it is impossible now to read the same number of elements in the last caudal ossicle (B) which we find elsewhere posited for all other vertebræ of the spinal series, yet I hold it to be also impossible for any anatomist to contemplate the presential character of a caudal bone and remain unproductive of the idea that the caudal bone (B), as a centrum (5), is a proportional left standing after the metamorphosis of all its other parts. If, then, we agree to this, we must also agree to the fact that those very parts (1, 2, 3, 4, of A) which a caudal centrum (such as B) wants, are identical with those same parts which are left standing to other vertebræ. Now, when I find that a coccygeal ossicle (B, 5) holds series with the centra (5) of all other vertebræ, I have every reason to name it as being the centrum of its own vertebra, which has undergone metamorphosis; and therefore I may conclude that the plus original of the caudal ossicle (B, *fig.* 449.) is equal to A, or to any other vertebra of the spinal series. It will be sufficient to the present argument, which holds comparison in order to establish the ideas of original or archetype uniformity, that we clearly understand how the original or archetype of a coccygeal bone is equal and uniform with any other vertebra of the spinal axis. The coccygeal bones (B) as nature presents them to us are vertebral centra, having had subtracted from them their spinous (1), neural (2), and costal elements (4); and under this interpretation we may have as strong an idea of the whole or plus quantity (A) of which caudal bones (B) have been metamorphosed, as if we saw those quantities still persisting entire. The difference between any of the costo-vertebral spinal segments and a caudal bone is like the quantitative difference between $a+b$ and $a-b$. Thus A, *fig.* 449., minus the elements 1, 2, 3, 4, equals B; while B plus the elements 1, 2, 3, 4, equals A.

Prop. XI. *The first seven thoracic costo-vertebral figures are whole or plus quantities.* —In no one respect do the first seven thoracic costo-vertebral figures (all equal to *fig.* 450.) differ from each other; in each of them may be counted the same elemental pieces; and those pieces of each (marked as in *fig.* 450.) are identical or homologous both as to position, use, mode of growth, number, and linear order. These elements consequently bear the same name in each, and most properly, because the corresponding pieces of each are absolutely similar. Consequently, also, the whole quantities (such as *fig.* 450.), which are

Fig. 450.

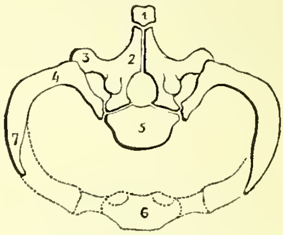


compounded of those pieces (1, 2, 3, 4, 5, 6, 7), should properly bear the same name; and therefore I call them sterno-costo-vertebral circles. There are, then, seven whole segments (such as *fig.* 449.) of the human spinal axis, which absolutely resemble each other in quantity. These segments are posited in linear order, and by this arrangement they yield an absolute linear uniformity. Such linear uniformity is evidently the result of quantitatively equal figures being posited in serial order; these figures enclose the thoracic space completely; and, because they severally manifest an equal number of homologous elements, so is it impossible to read any condition of specific variation between them. As archetypes, or whole quantities, of the mammal spinal axis, these seven thoracic sterno-costo-vertebral figures have no special diversity. When we compare them with one another we discover no more distinction between them than we find between the serial quantities $a+b$, $a+b$, $a+b$. It is quite true, therefore, that there is at least one regional department of the mammalian spinal axis, to which we may apply the name of absolute uniformity, as fittingly as we might apply it to a linear series of circles. And it is, moreover, true that the thing called species is, so far as regards this linear series of plus thoracic figures, as perfectly absent, as if it were non-existent everywhere. But yet it is possible for nature to work specific variety from out of this linear series of thoracic archetypes (such as *fig.* 450.). And how may nature effect this? Just in the same mode as she effects it in the creation of skeletal bodies comparatively contemplated, and this mode is the sub-

traction of quantity from whole or archetype originals. If nature arrested the development of, or, what amounts to the same result, if she subtracted different elemental parts from different regions of these several thoracic costo-vertebral archetypes; if she subtracted the spinous process (1) of one, the sternal element (6) of another, the rib (4) of another, or the spinous process, sternal piece, and ribs of another, then the remainders of those once uniform whole plus quantities would represent specific distinctiveness to each other. The remainders of the plus or whole quantities would then be the variable proportionals of such plus figures; and, being proportionals, would therefore be proportionally, that is to say specifically, various to them and to each other. Therefore I conclude that such species results not by the positing of new and unknown quantity, but by the annihilation or degradation of already known and posited quantity. In the plus figures (such as *fig.* 450.) we therefore discern not only the already create and positive entity of uniform quantity, but even every condition of possible variety or species which can result by a subtraction of their elemental parts.*

Prop. XII. *The five asternal costo-vertebral forms are proportionals metamorphosed from five sternal costo-vertebral plus quantities.*— The thoracic region of the human spinal axis consists for the most part of twelve costo-vertebral spinal segments. Seven of these enclosing space completely, arch forward and join at the sternal median line (*fig.* 450. 6). Five of these (such as *fig.* 451.)

Fig. 451.



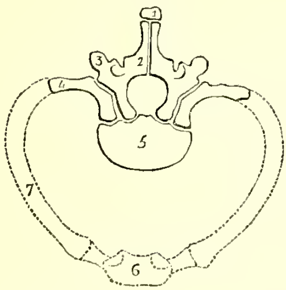
do not enclose thoracic space completely, but fall short of this sternal median line (6) more or less (as at point 7, *fig.* 451.); and in this respect the five asternal costo-vertebral segments are specifically distinct from the seven sterno-costo-vertebral plus forms. This distinction or species is evidently owing to the subtraction of costo-sternal quantity (7 to 6) from the asternal five forms (such as *fig.* 451.), which costo-sternal quantity is persistent for the seven sternal forms (such as *fig.* 450.). The loss or subtraction of the sternal piece (from 7 to 6, *fig.* 451.) becomes the advent or presence of the specific difference between *figs.* 450. and 451.; and hence it becomes clearly apparent that the law which exercises in creation of such difference between the sternal and asternal spinal segment is one of subtracting quantity from whole or plus forms, from which it is self-evident, that as the quantity of a sternal element and sternal costal pieces is that which is subtracted from the now asternal costo-vertebral segment (*fig.* 450.), so the original or plus quantity of this latter figure is of sternal costo-vertebral integrity or entirety, as I have drawn it in dotted outline for *fig.* 451.

Prop. XIII. *The five lumbar vertebræ are proportionals metamorphosed from five sternal costo-vertebral archetypes.* — The seven sternal costo-vertebral circles are succeeded by the five asternal costo-vertebral proportionals, and these latter by the five lumbar vertebræ. In this series of spinal segments it is easy to distinguish a descending scale of proportional quantities, whose only difference is one of quantity. This quantitative difference is exercised upon the costal elements only. In all other respects the lumbar and thoracic segments are similar; for in both orders of structures we find the same elements, such as spinous processes, transverse processes (the tubercle being the transverse process of the lumbar vertebra), centra, and neural arches. In both we also find the costal appendages, but these are not of equal growth or quantity. It is quite true, however, that the sternal costa is serially succeeded by the asternal costa, and this by

* This whole or plus segment of the mammalian spinal axis, to which I give the simple name costo-vertebral quantity, may appear at first sight to be the same as the "typical vertebra" of Carus, Owen, and others; but it is not so in fact, nor are the ideas which I entertain of the plus form, compared with other vertebræ of the same spine or different spinal axes, the same as theirs. I do not, for example, think it necessary to see in the typical form so many elements and parts as those which Professor Owen names, in order to render it inclusive or archetypal of all varieties of vertebræ, which, in addition to the centrum, the neural arch and spine, and the costal hæmal arch and spine, seem to produce such other elements as he calls zygapophysis, diapophysis, parapophysis, distinct. If I can prove that the ventral costo-sternal pieces, under a process of metamorphosis or degradation, suffer for the creation of such variety as we find ventrad of all vertebræ whatever, then must it be evident that the simple costo-vertebral quantity, as I have drawn it, is all-sufficient as the archetypal whole composed (dorsad) of a neural arch and spine, and (ventrad) of a hæmal arch and spine, together with their point of union — the vertebral centrum. If I can show that the lumbar "transverse process" and the anterior piece of the cervical transverse process (both of which are named "parapophysis" by Mr. Owen) are actually of costal growth, — the remains of the degraded plus ribs of a thorax, then there will be no need of them as distinct elements from ribs in my archetype or plus figure. Neither will it be required for my typical spinal figure that I should introduce into its proportions the parts called hæmal arch and spine (the chevron bones) as things distinct from the ventral costal circles (the pleurapophyses), while I see good reason to believe the former to be the ribs themselves somewhat degraded. In short, while I see it possible to interpret many of those elements which have been gathered together by the philosophic anatomist, as being necessary to the sum of his typical form, to be in reality but varying proportionals of the same whole quantity, so shall I be enabled to divest my typical form of all needless complexity, and set up simplicity in its stead.

the lumbar "transverse process" or costa; and this serial order clearly indicates that these are of the same original, but created specifically diverse by undergoing metamorphosis quantitatively. The originals, therefore, of the lumbar vertebræ must have been such as the sternal costo-vertebral circles, and I have drawn this original quantity in dotted outline for *fig.* 452., for it is true

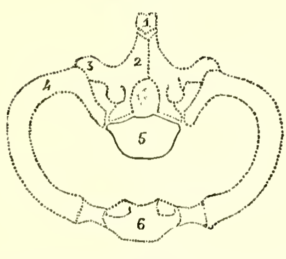
Fig. 452.



that the presential proportional condition of lumbar vertebræ, consisting of the elements 1, 2, 3, 4, 5, *fig.* 452.), manifests no other variety or species to the archetypal quantity 1, 2, 3, 4, 5, 6, 7, elsewhere persisting, than a simple quantitative variety.

Prop. XIV. *The sacro-coccygeal series of vertebræ are proportionals degraded from sternal costo-vertebral circles.*—That which is true of lumbar vertebræ, compared with thoracic segments, must be true of sacral vertebræ compared with the same. For as it seems that lumbar vertebræ are the proportionals of sternal costo-vertebral circles, so must sacral vertebræ, which are developed of elements identical in all respects with those of lumbar vertebræ, be proportionals of the like whole quantities or originals. And this is what I affirm of both sacral and coccygeal spinal segments.

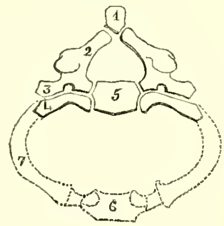
Fig. 453.



The last caudal bone, equal to the centrum (5, *fig.* 453.), being a spinal centrum itself, is the vanishing point of the series. The next degree of subtraction is annihilation of all quantity proper to the costo-vertebral original whole quantity, the complement of which I have drawn as the parts marked 1, 2, 3, 4, 6 around 5, *fig.* 452., thereby equating it with the plus thoracic form.

Prop. XV. *The seven cervical vertebræ are proportionals degraded from seven sterno-costo-vertebral whole quantities.* — The same elemental quantity which is proper to a lumbar vertebra is to be found in a cervical vertebra. In both (vide *figs.* 445. and 447.) we distinguish the centrum (5), the neural arch (2), the spinous (1), and transverse processes (3), and the costal rudiments (4). In both we find that the difference which they manifest on comparison with the costo-vertebral thoracic archetypes is simply a difference in costal quantity; and hence the same reasons which have been here advanced for regarding the lumbar segments as proportionals of sterno-costo-vertebral circles, may be also applied as proof of the truth of the interpretation that cervical vertebræ (such as *fig.* 454.), are also proportionals of the like

Fig. 454.

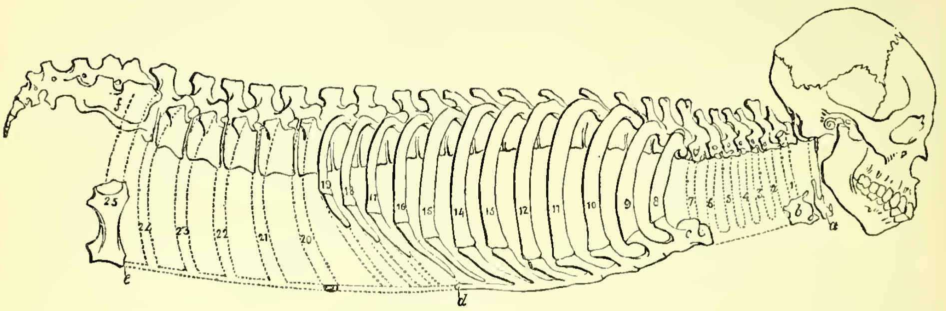


whole originals, and therefore I have equated it with the thoracic whole quantity.

Prop. XVI. *The mammalian spinal axis consists of a series of segmental quantities, whose only variety or specific distinction depends upon proportioning from whole thoracic quantities.* —The truth of this proposition has been established by the foregoing remarks. All the spinal segments of those regions of *fig.* 455., named cervical, thoracic, lumbar, sacral, and caudal, are not uniform, because they are not equal quantities. A cervical uniformity throughout the spinal axis would require that all the serial segments stood in cervical quantity. A lumbar uniformity would require all the serial segments to be of lumbar quantity. The same with respect to sacral uniformity; and the same of caudal uniformity. A thoracic uniformity would also require the spinal axis to be of thoracic sterno-costo-vertebral quantity from cranium to the other extreme of the same linear series, such as is represented in *fig.* 455., where the ribs are indicated in dotted outline in the neck from 1 to 7, and in the loins from 20 to 24. In neither of these conditions is the mammal spinal axis developed; and therefore it is that the original plus uniformity of all the segments from 1 to 25 is interrupted, the serial quantities being now developed of thoracic or plus, and of minus or cervical and lumbar, &c. proportions. Now as to the just interpretation of the natural law which creates this *figure* 455., thus composed of spinal segments in plus and minus variety, I apprehend that it is more rational to regard nature as being an artificer who, after creating a prime-model of whole or entire dimensions (such as *fig.* 455.), with the ribs

and sternum drawn at neck and loins, as well as thorax, degrades this prime-model to the dimensions of a specific or proportional variety, by obliterating costal quantity at neck and loins, than to understand her as having first given creation to an ens of lesser proportions (such as *fig.* 455.), with the cervical and lumbar vertebræ lesser than

Fig. 455.



The Mammalian Skeletal Axis,

Showing in dotted outline at the neck and loins those costo-sternal quantities which, if present, would render these regions equal to, and uniform with, the thorax.

those of the thorax, and then varied all other forms to this ens by a superaddition of new and hitherto unknown elements. The former idea is that which I am endeavouring to establish throughout these propositions. Original uniformity, or the prime model or archetype, viz. *fig.* 455., with the costo-sternal quantities at neck and loins, is that figure whose proportions I mean to develop by my mode of comparison; and the idea that the degradation or subtraction of parts proper to this archetype is that law which becomes the creator of specific variety. When I find that the osseous quantity of a caudal centrum, a sacral, a lumbar, or a cervical vertebral quantity can severally be referred to the like quantities contained in a sternal thoracic costo-vertebral segment*, I entertain the opinion that the latter, as a whole or prime model, has undergone metamorphosis to the creation of such proportional variety as the former instance: and this opinion, I fancy, is more consonant with reason, or is, at least, more pliable for understanding, than to suppose that nature, after having first given creation to the caudal, lumbar, or cervical segments of the spinal axis, created, as it were by after thought, other figures secondary and special to such as these by the addition of new and unknown elemental structure, such as a thoracic rib and a sternal piece; for in the absence or presence of certain elements consists all the specific difference between all segments and regions of the mammalian spinal axis.

Prop. XVII. *Uniformity of structure is a condition proper to the plus thoracic originals of the spinal axis of the mammalian body.*—It is a demonstrable fact, that all the spinal segments of those regions (*fig.* 455.), named cervical, lumbar, and sacral, differ from the first seven thoracic costo-vertebral circles (those numbered from 8 to 14) by quantity only; and this quantity is costo-sternal. It is also demonstrable, that the coccygeal segments of the spinal region, represented by the centrum (5, *fig.* 453.), differ from the same whole forms by quantity only: this quantity is the neural arch and spinous process, in addition to costo-sternal elements, all of which I have drawn in dotted outline around the caudal centrum (5, *fig.* 453.). Now this differential condition, visible between all such spinal segments, being one of quantity only, it must appear evident that the idea of a structural uniformity can alone be established, first by interpreting the present condition of cervical, lumbar, sacral, and caudal segments, as being one of proportional variety; and second, by comparing them as such with their originals, which I assert to be of sternal costo-vertebral quantity. If, then, the original or archetypal quantity of a caudal, a sacral, a lumbar, or a cervical segment be a sternal costo-vertebral segment, it will follow that the series of such originals constitutes plus uniformity, as indicated in *fig.* 455., whose serial units at neck and loins are equated with the thoracic units, whereas the series of such segments as cervical, lumbar, sacral, and caudal quantity constitutes proportional variety or specific difference, created out of the substance of the uniform archetype costo-vertebral originals. In order to fix the idea

* Every lesser unit of the vertebral chain finds its quantitative homologue in a part of the greater unit, and all lesser units in the greatest unit, which I therefore name as the archetype. In the following beautiful sentence, Carus expresses his idea of the organic whole quantity compared with the lesser thing or species: — "La partie d'un tout organique est incontestablement douée d'un organisation d'autant plus élevée qu'elle repéte plus parfaitement en elle l'idée du tout, et le tout lui-même est d'autant plus parfait qu'il correspond d'avantage à l'idée de la nature entière dont nous dévons reconnaître que l'essence est l'unité des lois éternelles révélées dans l'infinie diversité de la manifestation." See C. G. Carus, Traité Elément. d'Anatomie Comp. c. xi. p. 26., traduit par J. L. Jourdan; see also Carus, Von den Urtheilen des Knochen und Schalengerüstes, fol. Leipzic, 1828.

of uniformity throughout the serial line of spinal segments such as they are, we must submit them to a mental process of comparison which is to tell us what they once were. For as it is evident that these segments are only proportionally various, so is it equally evident that their plus originals must be uniform and absolutely similar. When I compare a caudal, a lumbar, or a cervical segment with a sternal costo-vertebral segment, I must acknowledge to a specific difference existing between these bodies; but then I also have every reason to believe that this specific difference is only a proportional difference.* If, then, the cervical, lumbar, or caudal segment shall severally prove to be parts or proportionals when they are compared with a sternal costo-vertebral segment standing at the thorax, it cannot be erroneous to read them as having been metamorphosed *from their own originals, such as those of the thorax*, and hence I conclude that uniformity alone characterises the series of such originals.†

Prop. XVIII. *Every spinal segment which is lesser, refers to every spinal segment which is greater; and all lesser segments refer to that which is greatest.*—If it be easy to conceive that the last caudal bone (I, *fig.* 444.) is a lesser quantity metamorphosed from such another quantity as the penultimate caudal bone (H, *fig.* 444.), where can be the difficulty in rationally interpreting both to be as quantities metamorphosed or proportioned from such quantities as lumbar vertebræ (E, *fig.* 444.), and hence from such segmental quantities as sternal costo-vertebral plus forms (such as *fig.* 453.). I could not entertain this idea of a caudal bone, if I found that it were an ens holding within its dimensions any elemental part which may not also be found to be contained in the plus form of *fig.* 450.; or if it were not the fact that the archetype (*fig.* 450. or 453.) could undergo a simple graduated metamorphosis of its parts (1, 2, 3, 4, 6), so as to simulate any other segment of the spinal axis lesser than itself.‡ A caudal ossicle, such as the centrum (*fig.* 453. 5), reminds me as strongly of its original whole quantity, viz. *fig.* 453., from which it has been metamorphosed as a dorsal spinous process (1, *fig.* 450.), separated from that thoraeic segment, reminds me of the whole of such segment. If it be true that I could never thus interpret the caudal ossicle, if I had not seen the thoracic archetype, this can be no argument to show the error of my interpretation; for it is equally true, that I could never know of what whole figure the dorsal spinous process was a part, if I had not seen the thoracic segment named costo-vertebral.*

Prop. XIX. *Structural uniformity cannot characterise such spinal segments as are proportionally or quantitatively various.* — A cervical segment differs from a thoracic segment by existing quantity; and the like difference prevails between all other segments of the spinal series, therefore those segments cannot be termed uniform. But though these segments are not uniform by reason of their being unequal things, still it is most true, that they are only diversified by reason of their quantitative inequality. In *fig.* 455. all the spinal segments are rendered plus and equal, by supplying in idea the osseous quantities lost at neck and loins.

Prop. XX. *Specific variety is none other than proportional variety.*—A cervical, a lumbar, a sacral, or a caudal spinal segment is various to a thoracic segment, forasmuch only as the former fall short of those parts which are proper to the latter figure, and therefore I say that specific variety is none other than proportional difference. For when, as in *fig.* 455, we equate those segments which are proportionally different, we re-establish uniform series.

Prop. XXI. *The knowledge of the differential quantity between all spinal segments renders them exactly uniform in idea.* — Upon holding comparison between one spinal segment and another, when I find that certain persistent parts of the segment of greater dimensions, viz. that of the thorax (*fig.* 455.), are those which are subtracted from the segment of lesser dimensions, viz. that of the neck or loins (*fig.* 455.), this is tantamount to the knowledge that the lesser segment has lost those parts which are persistent for the greater. And therefore I say, that in the knowledge of those parts which are wanting

* The number of proportionals capable of being struck from a whole quantity being of infinite amount, it will be also seen that the number of species which those proportionals themselves represent are likewise infinite. "Species autem illa abscissio infinite recte vocari possit." Bacon, Nov. Organon Scientiarum, Aph. 26.

† The series of the archetypal sterno-costo-vertebral circles constitutes absolute uniformity; and when we contrast with this quantitative uniform line this other line of graduated proportional serial quantities, such as the present state of the mammal skeletal axis exhibits them, we are enabled to estimate the law which has created the line of proportional quantities such as we find it. When the special or proportional thing is contrasted with the uniform whole or complete quantity, the contrast gives the interpretation. If species arise from the infinite subdivision of the line of whole quantities, then this latter, as perfect quantitative uniformity, may be defined as follows: — "Unitas (uniformitas) est sine commissura (sine hiatu) continuatio." Seneca, Natur. Quæst. lib. xi.

‡ "The great advantage of this idea of a whole is, that a greater quantity of truth may be said to be contained and expressed in it." Sir Joshua Reynolds' Discourses, Discourse xi.

* The self-evident truth which attends the geometrical axiom, that *the whole is greater than its parts*, needs no comment to sustain it; but that the part standing alone *per se* still refers to the whole quantity of which it is the part, requires to be insisted upon much oftener, for at first sight we are apt, without reflection, to regard it as it is in the light of a perfect figure. How many anatomists are there who never waken to the idea, that every lesser segment of the spinal axis refers to the greater whole quantity; and yet in this interpretation the law of formation enshrines itself. "L'ensemble de tous les ordres de perfections relatives, compose la perfection absolue de ce tout." Bonnet, Contemp. de la Nature, part i. chap. iii.

to the lesser, I may idealise it by a mode of equation to uniformity with the greater. For while I find reasons to believe that the spinal segment (*fig.* 454.), which is now in cervical form as consisting of the parts 1, 2, 3, 4, 5, has lost its sternal piece (6) and most part of its lateral costæ or ribs (7), then I have only to supply in idea the sternal piece and costæ to the cervical vertebra, in order to equate this segment to the thoracic plus character of *fig.* 450. The same mode of comparison carried out through all the serial segments of the spinal axis, will likewise render them in idea all equal to thoracic costo-vertebral archetypes, as seen in *fig.* 455.; and this is the mode of comparison by which alone the anatomist can understand the law of skeletal formation.

Prop. XXII. *Without knowing the full dimensions of whole or uniform quantities, we can never rightly understand the real character of lesser and special forms, and therefore can never otherwise understand the law of formation.* —The object of the present mode of comparison is, to ascertain the exact forms of whole quantities or archetypes, and the means adopted to this end is the synthetic mode. This object, and the comparative method by which I here endeavour to prove the existence of it, differs from all other methods hitherto adopted by comparative anatomists in search of the true interpretation of skeletal fabrics and the law of unity in variety. I mean to show that anatomical science can never know the figure of skeletal unity or uniformity until it shall know the archetype or prime model of complete dimensions from which all skeletal fabrics are fashioned; and, furthermore, that it can never comprehend the source of variety or specific difference until it shall interpret this as attaching to variable figures of osseous quantity degraded from the archetypes, and hence that it can never understand the law of skeletal formation in any other light rationally, unless in the sense of a law of degradation from whole or archetype skeletal fabrics.

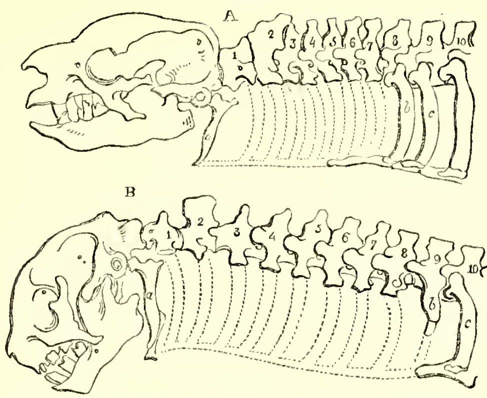
Now it appears to me, that by means of the mode of comparison which I here make use of for ascertaining the whole original or archetype quantity from which such a fabric as the mammal spinal axis (*fig.* 455.) is fashioned, we may also define as clearly the originals or archetypes of a large number of spinal axes throughout the classes of mammals, birds, reptiles, &c.; for, no doubt, what is true of one form must be likewise true of plural numbers of forms, such as skeletons which manifestly bear a remarkable analogy the one to the other. The same law of degradation by which a cervical, a lumbar, a sacral, and a caudal ossicle happens in the mammal spinal axis, appears to me to give a complete solution of the more extended problem, viz. how it happens that animal spines of all classes present differences in the cervix, the thorax, the loins, the sacrum, and the caudex. For while I find, by comparative reasoning held upon the serial segments of the one mammal spine, that a cervical or lumbar, &c. segment has actually lost costo-sternal quantity, and that by this loss it now differs from a thoracic costo-vertebral archetype, it must follow that the original or whole archetype quantity of a cervical or lumbar spinal segment is the equal of a thoracic costo-vertebral segment; and the very same reasoning lends a true interpretation to all cervical, or lumbar, or sacral, or caudal segments wherever they appear, whether in the class mammalia, birds, reptiles, &c.

Uniformity must, therefore, alone characterise the original archetype series, not only of all spinal segments such as they appear in the one spinal axis (*fig.* 455.), but the like original archetypal uniformity must be that whole quantity from which all segments of all spinal axes have been degraded. And diversity or specific difference will at the same time get its proper interpretation; for if a mammal cervical vertebra be diverse to a costo-vertebral thoracic archetype by reason of being proportionally different, and rendered so by the simple subtraction of its sternal piece and ribs, then, as the like difference or variety characterises all cervical or lumbar segments of animal skeletons of the classes mammals, birds, reptiles, &c. from all thoracic costo-vertebral archetypes of the same animals, it will hence appear that such diversity or specific variety has originated by the law of proportioning from whole archetype quantities. I draw the conclusion, therefore, that as an archetype series of sternal costo-vertebral segments, ranging from 1 to 24 of *fig.* 455., is the original of the mammal spinal axis, so may it be inferred that such an archetype series is the original of all spinal axes, whatever be their existing variety; and the law by which such variety occurs is the simple process of degradation or subtraction from the archetype series of sterno-costo-vertebral segments. There can, I believe, be no other true interpretation of the law of unity in variety than this.

Prop. XXIII. *The mammalian cervix is not limited to the fixed number of seven cervical vertebræ.* — A general rule may have exceptions, and anatomists may still indulge the assertion, that "the exception proves the rule;" but, as I take it, the exception only proves that the rule has a flaw in it, and that such exception can prove nothing more than this, namely, that error rests somewhere in our inpretations of the law of formation. When I say that there are many grave exceptions to the general rule that the mammal cervix is developed of *seven* cervical vertebræ, I am but recording facts — anatomical facts — which are exceptions to the rule. And while I here endeavour to develop the true evidence of the universal law of formation, I do not purpose doing so irrespective of those exceptional facts, for I believe that they must be interpreted before the law can be established truly. The neck of one species of sloth (B, *fig.* 456.) possesses nine cervical vertebræ, while the neck of another species (A)

contains seven. The human cervix (B, *fig.* 457.) occasionally develops only five or six. I have seen some species of the monkey tribe wherein the cervix counted only five or six; and I have no doubt, that if we dissected other mammalian bodies as frequently as we

Fig. 456.



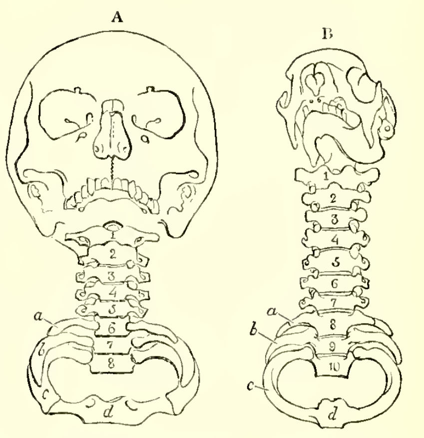
A, the neck of the sloth (*Bradypus didactylus*), representing the costo-sternal quantities lost to the seven cervical vertebræ; B, the neck of another species of sloth (*B. tridactylus*), exhibiting the loss of costo-sternal quantity, from nine cervical vertebræ. In both figures it is shown how the numerical difference of vertebræ of the cervix depends upon the number of metamorphosed archetypes.

do the human subject, we should find also in them many exceptions to the rule which we now call general.

But these exceptions will be called "anomalies" by the special anatomist. To this I answer, that if we understood fairly the true interpretation of the universal law, we should forthwith blot out the word *anomaly* from anatomical nomenclature; for there can be no anomalies any more than there can be exceptions to the universal law. Anomalies, such as they appear upon the bodies of one species, as, for instance, the cervical ribs (a, b) of the cervical vertebræ (6, 7 of B, *fig.* 457.), are, in reality, not more remarkable to the normal condition of that species than the figure and proportions of one species (A, *fig.* 456.) are to those of another and different species (B, *fig.* 456.). The same law presides over all conditions of formation.*

PROP. XXIV. *The number of cervical vertebræ in the mammal cervix depends upon the number of archetypal costo-vertebral figures which have suffered metamorphosis.*—Even if it were true that the mammal cervix invariably contains the fixed number of seven vertebræ, still there would appear no reason why we should not interpret the fact in the following mode, namely, that the seven cervical vertebræ of *fig.* 455. are those proportional osseous quantities left standing after the metamorphosis of the ribs (1, 2, 3, 4, 5, 6, 7) of seven costo-vertebral archetypes. For it is evident that cervical vertebræ do, like the thoracic figures, contain costal appendages, although in rudimental proportions. In the cervical vertebræ the costal pieces are *liable* to a plus condition (a b, of B, *fig.* 457.). In the thoracic vertebræ the costæ *are* fully produced.

Fig. 457.



A, the human cervix, numbering only five cervical vertebræ of normal quantity, owing to the presence of a, b, the cervical ribs persistent on the 6th and 7th vertebræ; B, the cervix of the sloth (*B. tridactylus*), which numbers as many as nine cervical vertebræ, in consequence of the metamorphosis of nine costo-sternal quantities.

If it were possible to raise a rational objection to the above mentioned interpretation of the cervical spinal region, I would then remark that "cervical ribs" do still further prove the truth of what I advance concerning this region of the spinal axis. For is it not true that when the sixth or seventh cervical

* "Tout phénomène dans la nature est lié à l'ensemble; et, quoique nos observations nous semblent isolées, quoique les expériences ne soient pour nous que des faits individuels, il n'en résulte pas qu'elles le soient réellement; il s'agit seulement de savoir comment nous trouverons le lien qui unit ces faits ou ces évènements entre eux." Gœthe, Œuv. d'Hist. Nat. Introd. p. xi. traduits par Martins.

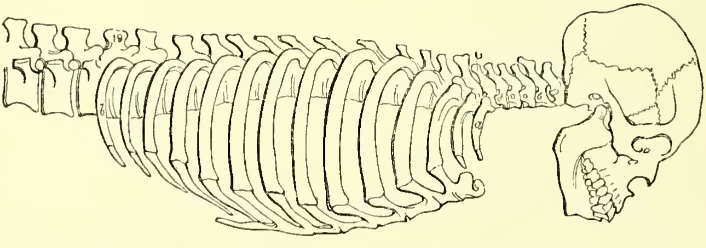
vertebræ of B, *fig.* 457., produce the costæ *a b* of greater dimensions than ordinary, these segments of the spinal axis are but resembling somewhat more completely the thoracic costo-vertebral archetypes (such as 8, *c*, *d*, of B, *fig.* 457.)?

Whenever, therefore, the sixth or seventh cervical vertebra produces the cervical ribs, I may interpret the occurrence of this "anomalous" fact in this way, viz. that a greater proportional of the archetype costo-vertebral quantity (such as 8, *c*, *d*, of B, *fig.* 457.) remains to the sixth and seventh spinal segment than is generally the rule. Cervical vertebræ, therefore, whether with or without the plus cervical ribs, are still the proportionals of full thoracic costo-vertebral forms; and the number of cervical vertebræ simply depends upon the number and degree of metamorphosis to which thoracic costo-vertebral forms have been subjected. When the cervix develops seven vertebræ of those proportions, such as we ordinarily find in the mammal body (A, *fig.* 456.), all we can say of it is, that seven thoracic archetypes have suffered metamorphosis of the ribs to the cervical degree; and when the mammal cervix exhibits only five or six vertebræ of cervical degree (B, *fig.* 457.), this occurs by reason of the fact that the seventh vertebra of B is not metamorphosed to cervical degree, but still retains a large proportional of the rib (*b*). When the mammal cervix (A, *fig.* 457., or B, *fig.* 456.) produces nine cervical vertebræ, then the simple interpretation is, that nine quantities, equal to those of the thorax, and which I have represented in dotted outline, have had the original plus costo-sternal quantity subtracted from them.

Prop. XXV. *The presence of cervical ribs subtracts from the number of cervical vertebræ, and adds to the number of thoracic archetypes.* —Whenever cervical ribs (*a*, *b* of B, *fig.* 457. and 458.) are produced upon the sixth and seventh cervical vertebræ, the numerical length of the cervical region of the mammal spine is diminished to the serial line of five cervical segments, which we call cervical vertebræ; and there and then by the occurrence of this fact, which subtracts from the cervical vertebral numbers, the thoracic costo-vertebral spinal region is added to and becomes numerically greater than we ordinarily find it. By as much as the ordinary cervical region is lessened, owing to the presence of cervical ribs, by so much is the thoracic region increased owing to the same cause, viz. the presence of cervical ribs. The converse of this condition would happen if ribs were subtracted from the thoracic spinal region; and we would then find that by as much as the thoracic region was lessened by so much would the cervical region be increased. What other rational interpretation can be given of this condition of balancing between the cervical and the thoracic spinal regions except this, namely, that the numerical difference of both regions occurs by the presence or absence of full costal forms; and that the condition of either region of the spinal axis is influenced by the simple law of subtracting the ribs from whole thoracic costo-vertebral quantities.*

Prop. XXVI. *The length of the thorax depends upon the number of persistent costo-vertebral archetypes.* — When I say that the numerical length of the cervix depends upon the number of costo-vertebral archetypes which have undergone a metamorphosis of osseous quantity down to cervical degree, it will follow that the numerical length of the thoracic region must depend upon the number of those original archetype costo-vertebral figures left standing in spinal series. That same law of formation which influences the numerical length of one spinal region must also influence the numerical length of the adjacent spinal regions, and so we invariably find this to be the case. When the cervix of *fig.* 458. produces cervical ribs *a* on the vertebræ 6, and

Fig. 458.



the next succeeding, the thorax is increased. When the loins produce lumbar ribs, succeeding the vertebra 19 *b*, the thorax is still increased. When the thorax is numerically lessened, by subtracting the ribs *a b* from the vertebræ 6 19, the cervical or lumbar spinal regions are numerically increased. Now all this variation in the spinal regions no doubt depends upon the number of persistent ribs, whether normal or abnormal. The degradation of the costo-vertebral archetype whole quantities, is the law which produces all minus or special variety, and

* As it seems that the presence or absence of the costal pieces varies the quantitative character of the vertebræ, making them thoracic by their plus presence, and cervical by their almost total obliteration, so the reader will, from this expression of the fact, readily gather the tendency of my remarks, which is this, namely, that the archetypal quantities of the cervical spinal region are equal to those which are still persisting for the thorax in full sterno-costo-vertebral proportions. This, be it right or wrong, is

yields the mammal spine as it is, normally or abnormally.

PROP. XXVII. *The numerical length of the lumbar spinal region depends upon the number of archetypes subjected to metamorphosis.*—The first lumbar vertebra, that which succeeds 19, *b*, *fig.* 458., counts twentieth from the occiput, and thirteenth after the last cervical vertebra, when this latter counts seventh from the occiput; and it is according to the character of the costal appendages of this first lumbar segment of the spinal series, that we are inclined to regard it as belonging to the category of thoracic or of lumbar spinal segments. When it produces articular costæ, it stands in true thoracic character, and adds to the number of thoracic segments, at the same time that it subtracts from the number of lumbar vertebræ. In this respect, namely, that of influencing the numerical series of the spinal regions according as the ribs are standing plus upon it or otherwise, this first lumbar vertebra is similar to the seventh cervical vertebra. As the numerical length of the cervix depends upon the presence or absence of cervical ribs, produced from the seventh cervical vertebra, and as this very condition influences also the length of the thoracic series, so does the numerical length of the lumbar region depend upon the presence of lumbar ribs produced in plus or minus dimensions from the first lumbar vertebra; and this is the very fact which also influences the length of the thoracic series. The inference to be drawn from these facts is obvious enough. The abnormal as well as the normal conditions of the lumbar spine, in regard to the ribs, prove that lumbar vertebræ, as well as cervical vertebræ, are proportional figures degraded from the costo-vertebral thoracic archetype quantities such as I have drawn them in *fig.* 455., from 1 to 24.

PROP. XXVIII. *The numerical length of the sacral and coccygeal series is not fixed, and this is owing to the same fact of archetypes undergoing metamorphosis.*— Though the human anatomist speaks of a spinal figure under the name of first sacral and first coccygeal vertebra, it is not hence to be inferred that this form presents, in all human spinal axes of a fixed and invariable character, either as to osseous quantity or numerical position. In order to prove that such is the changeable character of the form named sacral and coccygeal vertebræ, we have only to fix attention upon its numerical situation in several spinal axes of even human species; and we shall find that the first sacral vertebra of one spine is the last lumbar vertebra of another spine. In like manner we shall see that the first coccygeal vertebra of one spine is the fifth sacral of another spine. In the "normal" condition of the human spine, the first sacral vertebra (*fig.* 455.*f*) counts as the twenty-fifth reckoning from the occiput; but if we will compare and examine a large number of human skeletal axes, we shall see that the twenty-fifth spinal segment or vertebra is not always standing in sacral condition. I have found that this twenty-fifth spinal vertebra is sometimes in lumbar and sometimes in sacral form, a circumstance which proves that sacral character is mainly owing to the juxtaposition of the iliac bones. Upon whichever vertebra of the lumbar spine, whether it be *f*, or the one before or behind *f*, *fig.* 455., the iliac bones abut, this determines its sacral character. This sacro-iliac junction does not always occur between the twenty-fifth vertebra of the human spinal series and the iliac bone. I have occasionally seen it at the twenty-fourth and at the twenty-sixth numerical vertebra of spinal series. When the sacro-iliac junction happens between the twenty-fourth vertebra and the iliac bone, the human lumbar spine reckons only four vertebræ, provided the last thoracic be the nineteenth. When, again, this junction takes place between the twenty-sixth vertebra and the iliac bone, then the lumbar spine reckons six vertebræ provided always the last thoracic costo-vertebral segment be the nineteenth. These variations in the numerical length of the lumbar spine, occur according to the spinal position of the iliac spinal junction; and it will hence appear that the sacro-coccygeal series of spinal forms must also be influenced by the same facts.

PROP. XXIX. *A comparison of the same numerical vertebra in all human spinal axes will prove the truth of the present interpretation of the law which governs the development of all vertebral forms, not only in the same spine, but all other spines.* — When I say that the seventh cervical vertebra of *fig.* 455. is a proportional metamorphosed from its own costo-vertebral archetype or whole quantity, and which archetype is the equal of that which stands as the first thoracic costo-vertebral form, viz. that marked 8 in *fig.* 455., have I not a certain proof of the truth of this interpretation, when upon comparing this seventh cervical vertebra of *fig.* 455. with the seventh cervical vertebra of B, *fig.* 457., or that of *fig.* 458., I find that the very same numerical seventh cervical vertebra is, in the one skeleton (*fig.* 455.), of cervical, and in the other skeleton (*fig.* 458.), of thoracic character. For it is the presence or persistence of the cervical ribs which determines its character in this case as thoracic, and it is the absence or rudimentary condition of the ribs which in the other case stamps it as cervical. Again, when I say that the twentieth spinal vertebra of *fig.*455., reckoning after the occiput, and which twentieth vertebra is the first lumbar vertebra, must be considered as a proportional or lesser form metamorphosed from such another whole archetype as the

the idea I wish to create as contradistinguished from the ideas promulgated in "The Homologies of the Vertebrated Skeleton," where I find that the author, in his figures of the archetype of mammalian, avian, and reptilian forms, leaves their cervical regions standing in their class proportions, as though these were "archetypal," "the general," "the fundamental type."

thoracic costo-vertebral figure, have I not a proof of the truth of this reading in the fact, that this twentieth spinal vertebra in one spine presents in lumbar form, and in another spine in thoracic costo-vertebral form. How much closer can we urge the science of comparison to yield to us the secret of nature's law of formation than by comparing the same numerical vertebra with itself, and discovering that it is proportionally diverse in several individuals of one and the same species? If, therefore, the same vertebra be in many individuals in all those same conditions of proportional variety in which we find all vertebræ throughout the serial order of the one spinal axis from atlas to the last coccygeal nodule, — if this same vertebra (seventh) shall prove, upon a comparison of it in many animal skeletons, of the same variable proportions as we find to exist between a cervical, a thoracic, a lumbar, a sacral, and a coccygeal vertebra in the same spine, it must be evident that the law which governs the proportional variety of the same vertebra in many animals is the same as the law which governs the proportional variety of all vertebræ in the one animal. So true is this that I hold it to be possible to take the same spinal vertebræ of normal and abnormal condition from a plurality of skeletons, and construct with them a spine of the same quantitative variety as it exhibits in the serial line of cervical, thoracic, lumbar, sacral, and caudal vertebral regions.

Prop. XXX. *The anomaly is a link in the chain of form.*—False interpretation of the law of form is the source of all those conditions which are spoken of as being anomalous to the law. When anatomists name cervical or lumbar ribs as being anomalous to the human neck or loins, it is a proof that they do not understand the law of development which governs the human and all the general connected chain of special variety. The anomaly (6 *a* of *fig.* 458.) is to the normal form of the same cervical vertebra of *fig.* 455. just what one normal form (19 *b*, *fig.* 458.) is to the other before or behind it in series. The cervical and lumbar ribs are to the cervical and lumbar vertebræ just what the thoracic ribs are to the thoracic vertebræ. And the seventh cervical and first lumbar vertebræ, whether these produce the rib in plus or in rudimental form, are to each other just what ordinary cervical and lumbar vertebræ are to thoracic costo-vertebral archetypes, namely lesser quantities metamorphosed from greater quantities. Hence does it plainly appear that normal as well as abnormal cervical and lumbar vertebræ are alike only proportionally various to thoracic costo-vertebral archetypes, and hence may it be understood that all variety, whether normal or abnormal, springs by the simple metamorphosis of the archetypes, indicated in dotted lines at the neck and loins of *fig.* 455. While human anatomists falsely interpret the ordinary cervical and lumbar vertebræ as being whole quantities, then every elemental structure which occurs plus upon a cervical or lumbar vertebra, will by them be named "anomalous."* Cervical and lumbar ribs are thus accounted anomalies. But when we shall regard cervical and lumbar vertebræ through the medium of the idea here entertained of them, viz. that they are lesser things degraded, proportioned, or metamorphosed from greater whole quantities, such as costo-vertebral archetypes, then may we reasonably know the origin of cervical and lumbar ribs, and interpret these as being larger proportionals of the costo-vertebral archetypes than what we ordinarily find in cervical or lumbar regions.†

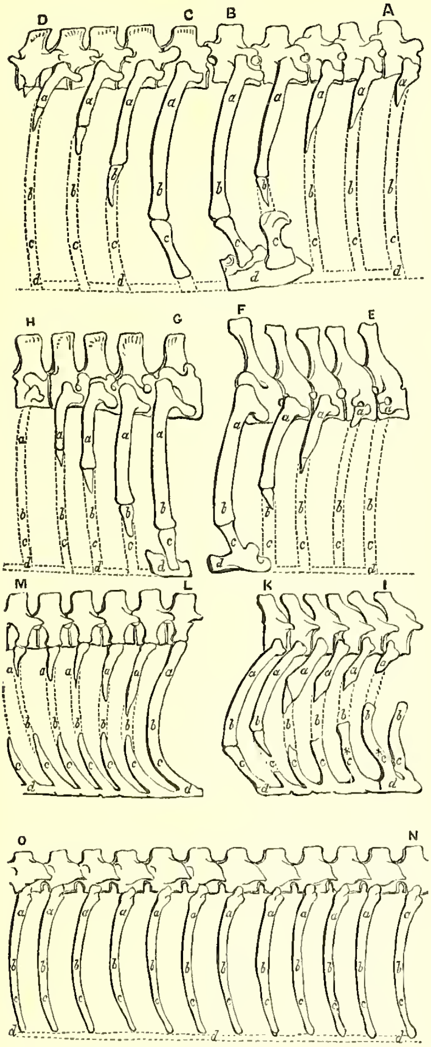
Prop. XXXI. *All the spinal segments of all classes and species of vertebrated animals are only as the variable proportionals of sterno-costo-vertebral archetypes.* — A comparison of those several regions of the spinal axes represented in *fig.* 459. will prove the truth of the assertion, that the law of formation by which all skeletal species are produced, and the law which produces the regional variety of cervical, thoracic, lumbar, sacral, and caudal in the one skeletal axis, are one and the same in operation. When I take the cervical spine of a bird (A B) (the ostrich), and compare it with the lumbar spine (C D) of the same animal, I find that both regions of the same spine present the like proportional character. The segment (B, *a*, *b*, *c*, *d*), which is the thoracic sterno-costo-vertebral archetype or whole quantity, is preceded by a series of proportional quantities gently graduated and declining into the cervical minus figure marked A, *a*. In like manner (C, *a*, *b*, *c*) the archetypal sterno-costo vertebral quantity, the last of the thoracic region, is succeeded by a series of proportional quantities, graduated in the same way, and declining into the lumbar minus figure marked D, *a*. Again, when I compare the human cervical spinal region (E F) which "anomalously" produces cervical ribs, with A B of the bird's cervix, which *normally* developes the cervical ribs, I only find a manifestation of the same law. And the bird's lumbar spine (G H) is only in the same way proportionally characterised as the bird's neck (A B), or the mammal neck (E F), or the

* "La loi de la continuité porte que la nature ne laisse point de vide (anomalie) dans l'ordre qu'elle suite." Leibnitz, Œuv. Philos. Nouv. Essais, liv. iii. p. 267.

† The continuity of the chain, not only of an animal kingdom, but even of the serial spinal axis, is so evident a truth, and so sound a generalisation, that when any form shall appear abruptly interrupting this continuity, and, as it were separating members of the chain apart and isolated from each other, it may be taken for granted that we are ignorant of its true nature, and its general and special relations to all other units of the series. The true object of science is the discovery of such points of analogy as will relate the anomalous form to the general chain of which it is a unit. The differential character of the thing or things is that which strikes the uninitiated at first sight always. "Itaque convertenda plane est opera ad inquirendas et notandas rerum similitudines et analoga, tam integralibus quam partibus: illæ enim sunt, quæ naturam uniunt, et constituere scientias incipiunt." — Bacon, Novum Organum, aph. xxvi.

lizard's neck (I K), or the lizard's loins (L M). Now as all the units of these several regions

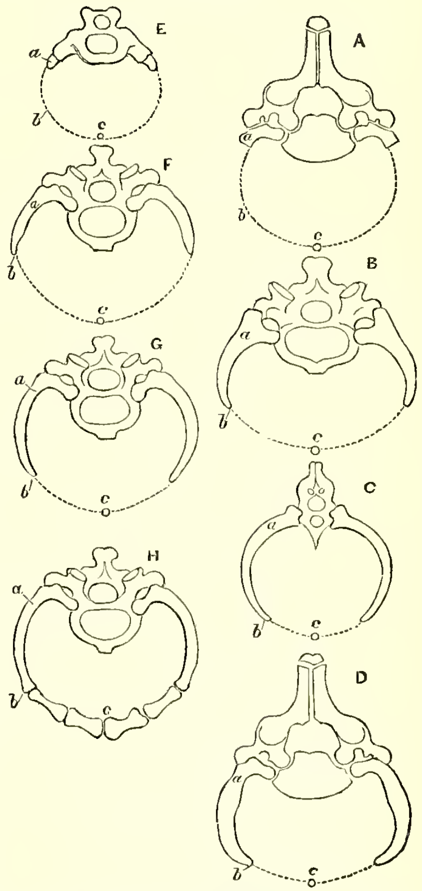
Fig. 459.



A B, C D, the neck and loins of the ostrich; E F, the human cervix, with cervical ribs; G H, the loins of a mammal; I K, the neck of a lizard; L M, the loins of a saurian (crocodile); N O, a part of the ophidian thoracic skeleton.

of the same and of different species, evidently illustrate the simple law of the archetypal plus ens of the thoracic sterno-costo-vertebral quantity, undergoing a graduated metamorphosis into less quantities of a neck or loins, so I have equated in dotted outline, all those parts which the minus quantities have actually lost; and thus I have in idea given creation to their whole or plus originals; and the reader will observe that by this very mode of equation between the plus and minus segments of A B, C D, E F, G H, I K, L M, I have equated them likewise with the plus series N O, which represents part of the ophidian thoracic skeletal axis. The fact likewise may be noticed in this place, which will be more fully considered hereafter, that in *fig.* G H the parts *b*, *c*, *d*, which are represented in dotted outline as the quantity lost to the shortened ribs *a*, *a*, are those very structures which in the saurian venter opposite its lumbar spine L M, appear as the ventral ribs (*c*, *c*), joining a ventral sternum (*d*, *d*); and there appears ventrad of the saurian cervix (I K) that series of osseous pieces marked *c*, *d*, amongst which I find the bones (*c***c**), known as clavicles and coracoids. Are these clavicles and coracoid bones which appear ventrad of the cervical spine, in reality only as persistent parts of the whole sterno-costo-vertebral archetypes?

Fig. 460.

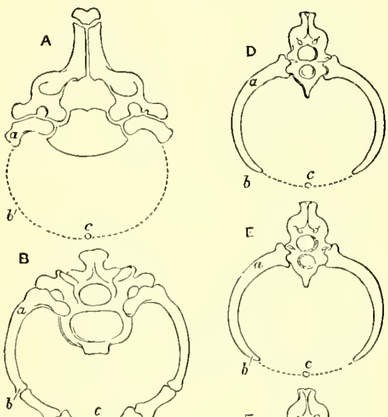


A, the seventh cervical vertebra of the human neck; B, the seventh of a bird's neck; C, the seventh of a serpent's spinal axis; D, the seventh cervical vertebra of the human neck, producing *a*, *b*, the cervical ribs; E F, G H, vertebral segments of the ostrich, taken from the caudex E, neck F, loins G, and thorax H.

When I compare all those spinal regions of several species of animals represented in

fig. 459., I find that the difference between them is resulting by a subtraction of different parts from each. But when guided by the light of comparison, I supply to each those parts which it has lost, then I render them all equal as whole quantities. Now, if the question be here asked upon what authority I act in thus equating the minus ens with the plus, by adding to the former that quantity by which it is less than the latter? I may answer that nature herself teaches me the rule in offering to my consideration the following facts: — In *fig.* 459. A B C D represents the same numerical spinal segment of different animals, and it manifests only a proportional variety. Again, I find that, numerically different vertebræ of the same spine E F G H, exhibit the same proportional variety. Again, I choose numerically different vertebræ from the spinal axes of different classes of animals (A B C, *fig.* 461.), and they present in the same

Fig. 461.



A B C, vertebræ taken from, the human neck (A), the bird's thorax (B), and the crocodile's loins (C); D E F, vertebræ from any region of the ophidian spinal axis.

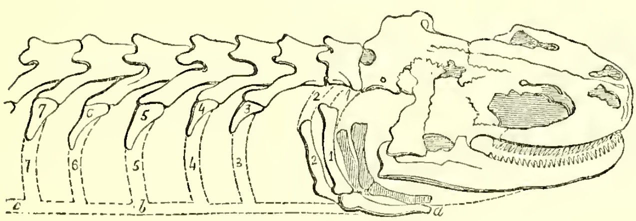
proportional variety; and, lastly, I take D E F numerically different vertebræ from the same spine, and they represent uniformity amongst themselves; but this uniformity is occurring only by reason of the fact that these units are of equal quantity. Now, upon comparing all those spinal segments of *figs.* 460. and 461., it becomes manifest that the thoracic or ventral circle *a*, *b*, *c*, which I have supplied in dotted outline for some, indicating the quantity lost or substracted, is actually created for others; and hence it appears that the only difference between them, one and all, is in that degree in which the rib (*a b*) falls short of the sternal median line *c*. The law of species therefore appears to be the law of proportioning lesser quantities from whole and complete quantities.

It is the metamorphosis of ribs at the neck, loins, sacrum, and caudex, which renders these regions different to the thorax. Between those spinal segments to which the plus ribs are present in one animal (B, *fig.* 461.), and those spinal segments from which the ribs are metamorphosed in another animal (A, *fig.* 461.), I hold comparison, and I find the rational conclusion, that the parts or ribs (*a*, *b* of A) which are absent from one class of vertebræ are identical with the parts or ribs (*a*, *b* of B) which are present to another class of vertebræ. And that specific difference, as it exists between two or more animals, is accruing by the loss of known parts, viz. ribs. For which reason I am led to name that skeletal form (N O, *fig.* 459.) which holds all its ribs (*a*, *b*, *c*,) to be archetype of all other skeletal bodies of the four classes from each of which variable numbers of original ribs are subtracted. And for the like reason, I say, that the thoracic region of the one skeletal axis which holds its ribs is archetype of all other regions of the same spinal axis from which the ribs have been metamorphosed. The law of formation therefore is the metamorphosis of ribs. The original or archetype skeletal axis is therefore one of costo-vertebral character from occiput to the extreme caudal tip. The metamorphosis of the ribs of this original, or archetype, or continuous series of costo-vertebral quantities, yields all species of skeletal axes. If all skeletal axes were similar in osseous quantity to the thoracic ophidian (N O, *fig.* 459.), there would be no specific variety, for all skeletal axes would then be similar to one another. But they are not all quantitatively similar, and this is the reason that they are specifically various, having severally lost various parts, which parts are to be read in the original, the uniformity, the archetype, the uninterrupted serial line of costo-vertebral spinal segments.

PROP. XXXII. *The Hyoid Apparatus occurs opposite to the cervical spinal region, where we know costal quantity to be lost. The hyoid apparatus refers to the cervical vertebræ, and consists of their ribs metamorphosed.* — Wherever plus or archetypal or thoracic osseous quantity persists complete in all its parts, there, in that place, we never find a new apparatus posited. It is as impossible for a new or specifically various apparatus to appear where archetypal osseous quantity exists, either among the four classes of skeletal forms, or the four spinal regions of the one skeletal figure, as it is for two things to occupy one and the same place. I call the thoracic sterno costo-vertebral apparatus the archetypal or plus quantity of the spinal axis, and I find

that, because it is plus quantity, no new apparatus ever appears, or can appear, at that locality which it occupies. Anatomical research has never yet discovered, and never can at any future time discover, a new and hitherto unknown osseous piece of any form or cast whatsoever at that spinal region where the thoracic apparatus stands fully created from the sternum in front to the spinal bone behind. Anatomical science may safely venture to predict that the searcher after variety and specific differences will never find in any skeletal form, whether of extinct species, of existing species, or as yet uncreated species, a new osseous apparatus happening where the complete thoracic apparatus occurs. It cannot occur at this locality, because the full archetypal osseous quantity is already existing in thoracic structure. There is no regional spinal variety, and no new or special apparatus, in the thoracic ophidian skeletal axis, because the full or archetypal osseous quantity already exists in the thoracic form. The ophidian skeleton has neither cervix, loins, sacrum, clavicles, coracoid bones, ventral apparatus, pubic bones, or marsupial bones, because the whole length of its spinal axis is already persistent in costo-vertebral thoracic character. If it be said that these various apparatus are not created for the ophidian skeleton, because they would not suit this particular cast of form, and that the "*nihil supervacaneum*," is a rule with nature in the construction of animal beings, I grant the truth of this most freely; but still I will maintain that this has no power to invalidate my present argument, which is conducted not to disprove design, but to demonstrate that all design occurs by the omission of elemental structure proper to plus archetypal structure. I grant that the ophidian thoracic skeleton, though deprived of all the above-named special apparatus, is as perfect in its own design as the "paragon of animals" himself is, or as any other cast of skeletal form furnished with those same apparatus; but yet I say that it is as impossible, as it would be unfitting, for creative force to give birth to such a form as the thoracic ophidian, and furnish it at the same time with clavicles, coracoid bones, ventral apparatus, marsupial bones, cervical, lumbar, and sacral vertebræ. Moreover, I assert it to be likewise impossible for creative force to produce any of those apparatus, or all of them, for a skeletal figure, if such figure were not at the same time to manifest a cervical, a lumbar, or a sacro-caudal spinal region. In whatever skeletal form the cervix or loins or sacro-caudal spinal region is developed, in this same form alone can we find the hyoid and ventral apparatus. It is quite true that a skeleton may be found characterised with the cervical and lumbar, &c. vertebræ, and yet not characterised with clavicles, coracoid bones, ventral ribs, or marsupial bones; but where these do exist, then such a spinal axis as that of the ophidian, consisting of costo-vertebral archetypes, cannot at the same time exist. The continuity of such a thoracic spinal axis must be broken directly any special apparatus, such as 1, 2 of *fig.* 462., or 1,2,3,4 of *fig.* 463., appears upon it. A thoracic skeletal axis, in

Fig. 462.



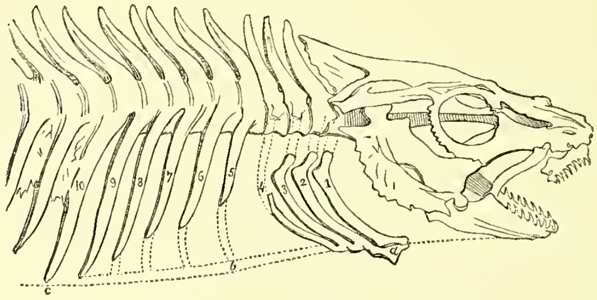
The cervical spine of the Menopone,

Showing that the hyoid circles 1, 2 appear as the ribs of cervical vertebræ, and hold serially related to those ribs 3, 4, 5, 6, 7, which, having been subtracted from the thorax, give to this latter its particular form.

order to be of what I call full plus archetypal dimensions, should present its spinal segments, one and all, from the skull to the other extreme, in sterno-costo-vertebral quantities, such as the thoracic spinal segments of the human skeletal axis. Upon such a skeletal axis there could not appear such an apparatus as the hyoid structure (1,2 of *fig.* 462. or 1, 2, 3, 4 of *fig.* 463.), or the clavicles, the coracoid bones, marsupial bones, pubic bones, or ventral apparatus, and for this reason, namely, that all the osseous quantity which goes to construct these, when fitness and special design demand their presence in the skeleton, must be drawn from the costal and sternal quantity of the continuous series of archetypes, and in such case the presence or creation of the hyoid species of apparatus must imply the metamorphosis of the other costo-sternal species of form. Now, the ophidian skeleton itself proves to be imperfect when compared to this standard skeletal figure, consisting of sterno-costo-vertebral archetypes; for the sternal median structure is lost to the ophidian throughout its entire length. In the ophidian skeletal axis, I find the cervical region, or that division of the spinal segments which immediately succeeds the occiput, having the costæ or ribs persisting; but those ribs are free, that is to say, they do not meet the sternal line in front. The sternal pieces and the sternal ends of the ribs are wanting; but in that very locality where these should appear, if the archetypal sterno-costo-vertebral segments were perfect

and enclosing thoracic space completely, appears the new apparatus named hyoid. The absence of the sternum and sternal ends of the ribs becomes the presence of the simple special design of an ophidian hyoid apparatus. By an actual necessity, therefore, and in the relationship of cause and effect, it appears that the presence of a hyoid apparatus (1, 2

Fig. 463.



The cervical spine of the osseous Fish,

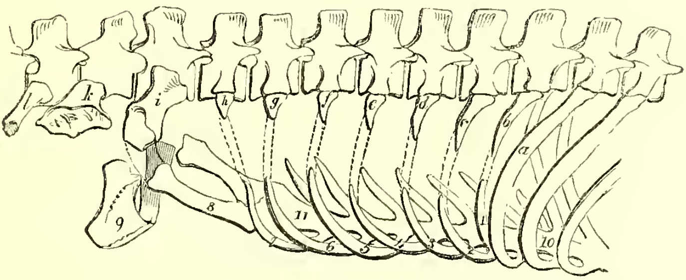
Exhibiting the hyoid apparatus 1, 2, 3, 4, as being the original costo-sternal quantity proper to those vertebræ which immediately succeed the occiput. In both *figs.* 462. and 463. the parts indicated in dotted outline are those quantities of the archetypal series of sterno-costo-vertebral circles which, being subtracted, give to both forms their class characters. If such parts still existed for both forms, these would approach the original character of plus uniformity, and thereby would leave no distinction between the hyoid apparatus, 1, 2, 3, 4, and the thoracic apparatus, 5, 6, 7. In both figures it will be marked that the variable number of hyoid circles depends upon the variable number of those costæ which have suffered metamorphosis.

of *fig.* 462.) must be the metamorphosis of a costal apparatus at those spinal segments which immediately succeed the occiput, and the same appears true of every other special apparatus produced upon the skeleton form. The appearance of any or all kinds of special apparatus implies the metamorphosis of all or some of the costal and sternal quantities. Consequently, therefore, it must follow that as the original costo-sternal apparatus of the cervical spinal segments may be regarded as homologous with the thoracic costo-sternal apparatus, so will the hyoid apparatus (1, 2, 3, 4, *fig.* 463.), which is constructed of the cervical costo-sternal quantity, bear some analogy, more or less, to the thoracic apparatus (5, 6, 7, 8, 9, 10, *fig.* 463.). In all skeletons I see an analogy, more or less strongly marked, between not only all hyoid apparatus as special designs (*fig.* 462, 463.), but between these and the thoracic apparatus. The source of this structural analogy, no doubt, is, that the hyoid apparatus (1, 2 of *fig.* 462., and 1, 2, 3, 4 of *fig.* 463.) is specially modified from the original structure at the cervix, which structure is costo-sternal proper to the cervical spinal region, and, as such, is the true structural homologue of that apparatus which elsewhere constitutes the thorax. The hyoid apparatus, at one spinal region, is not the thoracic apparatus at another spinal region ; for to assert this would be as absurd as to say that the thorax of one skeleton was the thorax of another ; in other words, as to assert that duality was unity. How can the hyoid apparatus (1, 2, 3, 4 of *fig.* 463.) be rationally named the thoracic apparatus, when both apparatus may exist at the same time in the same skeleton ? When I see the hyoid apparatus (1, 2, 3, 4) of a fish (*fig.* 463.) existing with the thoracic apparatus (5—10, *fig.* 463.), and both the same apparatus existing in a mammal skeleton (*a*, *b*, 8—19, *fig.* 455.), why should I therefore say that the hyoid apparatus of the fish was the thoracic apparatus of the mammal pushed upwards into the fish's throat ? If the hyoid apparatus of the fish were the thoracic apparatus of the mammal, then, strictly speaking, the fish could have no hyoid apparatus at all, and wherefore should we still continue to call that hyoid which in reality was thoracic ? Evidently anatomists are only disputing about the shadow of nomenclature in their ignorance of the real entity of form, and the law which modifies to infinite variety. Evidently, while they record how unity or uniformity is varied, they cannot describe or figure the character of unity, and they never will, so long as they dispute about variety without first ascertaining the source of this variety. What is the truth concerning the source of this remarkable analogy between all hyoid apparatus as such (in *figs.* 462, 463.), and all thoracic apparatus as such ? I believe the source of the analogy to be this, namely, that the thoracic apparatus happens at variable localities of the spinal axis, according to the position whereat sterno-costo-vertebral archetypal structure persists, as from 8 to 19 of *fig.* 455., and 5 to 10 of *fig.* 463. This thoracic apparatus may, according to necessity, persist at any region of the spinal length, or at all regions, because the original archetypal skeletal axis is one of a continuous series of thoracic segments. Where it does persist, as in *fig.* 463. from 5 to 10., there no new apparatus can recur ; but where the thoracic apparatus has undergone metamorphosis, as at cervix 1 to 7 of *fig.* 455., and 1 to 4 of *fig.* 462. or 463., there and there only a new special apparatus, such as the hyoid, can happen.

Where this original or archetypal thoracic structure suffers metamorphosis, as at the neck, there the hyoid apparatus appears as part of the original thoracic quantity, and hence it is that the hyoid apparatus, as such, bears an analogy with the thoracic apparatus as such, because the original of the former is thoracic quantity. When this original thoracic quantity undergoes metamorphosis immediately after the occiput, then the vertebral cervix is formed, and also the hyoid apparatus below it. As both these have come by the metamorphosis of costo-vertebral quantity, so do we find them bearing analogy to those segments, next succeeding them in spinal series,— those segments, namely, which persist as whole archetypes, and constitute the thorax.*

Prop. XXXIII. *The Ventral Apparatus occurs opposite to the lumbar spinal region, where we understand that costal quantity is lost. The ventral apparatus refers to the lumbar vertebræ, and consists of their ribs metamorphosed.*—With the mere change of name from hyoid to ventral apparatus, I may apply the foregoing remarks, which prove that the hyoid apparatus has come of the metamorphosis of the ribs of cervical vertebræ, to demonstrate, also, that the ventral apparatus (1, 2, 3, 4, 5, 6, 7, *fig.* 464.) has come of the metamorphosis of ribs proper to the lumbar vertebræ. As the original or whole archetypal quantities from which the hyoid apparatus and the cervical vertebræ have been metamorphosed are of thoracic or costo-vertebral proportions, so, in like manner,

Fig. 464.



The lumbar spine and ventral apparatus of the Crocodile,
Showing that the ventral ribs (1 to 7) are the proper continuations of the lumbar costal pieces, *b, c, d, e, f, g, h,* with which they correspond numerically.

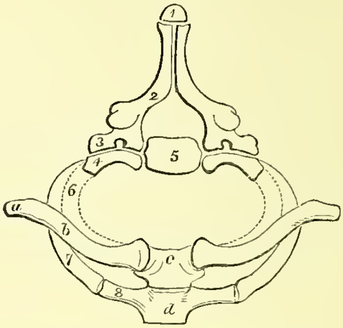
I believe that the original or whole archetypal quantities, from which the ventral apparatus (1 to 8, *fig.* 464.) and lumbar vertebræ (*b* to *h*, *fig.*464.) have been metamorphosed, are also of thoracic costo-vertebral proportions. In the ophidian thoracic skeleton, I find that that region of the spinal axis which corresponds numerically to the cervical region of the mammal spinal axis presents in thoracic costo-vertebral proportions; and therefore I say, that the true interpretation of the law of formation, which strikes the skeletal neck of the mammal specifically different to the skeletal neck of the ophidian, must be this, viz., that the costo-vertebral original of the mammal neck is equal and homologous to the persisting figure of the ophidian neck; but that metamorphosis has modified the original quantity of the mammal neck (*fig.*455.) to its existing apparatus of hyoid arcs *a b* and cervical vertebræ, whereas the original quantity of the ophidian neck still persists. In the latter we therefore find the cervix in thoracic costo-vertebral quantity, having appended to it, in front, the simple hyoid apparatus metamorphosed of the sternal elements. In the former we find the cervix consisting of vertebræ with stunted ribs, which are occasionally produced to more imposing proportions, being then called "cervical ribs" and still having appended to them, in front, the hyoid apparatus. The same interpretation will apply, also, to the mammal lumbar spine (*fig.* 455.), viewed in connection with the fibrous bands named "*lineæ transversæ*" (20 to 24) and "*linea alba*" (*d* to *e*). And still more evidently will the same interpretation apply to the saurian lumbar region (*b* to *h*, *fig.* 464.), and the ventral apparatus (1 to 7); for this latter structure is evidently composed of sternal and costal elements. What the hyoid apparatus is to the cervical vertebræ, namely parts of the thoracic original whole quantities, just in the same relation stands the ventral apparatus of *fig.* 464. to the lumbar vertebræ; for I regard both these latter structures to be parts, likewise, of the thoracic whole quantities. The hyoid apparatus refers to the cervical vertebræ, therefore, just as the costo-sternal structures of the thorax refer to the dorsal vertebræ; and in the same relation does the ventral apparatus of *fig.* 464. refer to the lumbar vertebræ. If we seek a proof still further that the original quantities of the cervical and lumbar regions of the spinal axis of any animal are thoracic costo-vertebral quantities, equal to those of the thoracic region of the same animal, we have this proof in the fact, that all the spinal

* Professor Owen considers the first circle of the fishes' throat apparatus as the only part of it which is homologous to that of other animals, and accounts all the succeeding arches (three or more in number, and all similar to the first, however,) as "appertaining to the system of the splanchno-skeleton, or to that category of bones to which the heart-bone of the ruminants, and the hard jaw-like pieces supporting the teeth of the stomach of the lobster, belong." See Homologies, &c.

regions of the ophidian are thoracic, and therefore in this skeleton there does not appear a cervical spine, or a lumbar spine, properly so called. If the above observations, respecting the several spinal regions, and the several apparatus thereunto appended, be true, then, however harshly it may seem to jar against reason, in asserting that there must exist the same analogy between a hyoid, a thoracic, and a ventral apparatus, as between the cervical, the dorsal, and the lumbar vertebræ, still I do not hesitate to make that assertion, under the knowledge that the original whole quantities of each region are of thoracic costo-vertebral proportions. I do not mean to say that the apparatus of the vocal throat (*a b* of *fig.* 455.), or the respiratory thorax (8 to 19 of *fig.* 455.), and the digestive venter (1 to 8 of *fig.* 464.), are identical as osseous quantities, having the same number of elemental pieces in each which we find in one, but what I distinctly repeat is this, namely, that, however broad may be the specific distinctions between the presential characters of a hyoid, a thoracic, and a ventral apparatus, when compared and contrasted with each other, still the law of serial arrangement will, if followed in the one skeletal form, and throughout the whole animal kingdom, prove that they are variable proportional osseous quantities of the same original, viz., the thoracic costo-vertebral continuous series of archetypes: and, therefore, I have united with dotted lines the hyoid apparatus to the cervical vertebræ, and the ventral apparatus to the lumbar vertebræ.

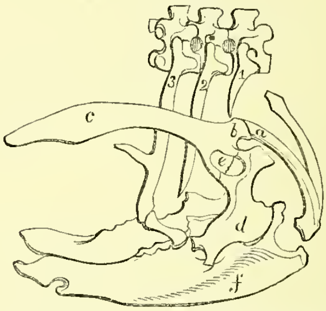
Prop. XXXIV. *Clavicles, coracoid bones, and ribs are identical parts of the costo-vertebral whole quantities or archetypes.*—It is impossible to tell which of the two bones named clavicle and coracoid, in a bird, is the counterpart or homologue of the bone named clavicle in man. Anatomists are not agreed upon this point at the present time; and, I may venture to say, they never will be, for this reason, viz., that they believe these bones to be specifically diverse bodies, and holding a permanently fixed character in all animals, when, in fact, they are identical bodies, being severally subjected to the same modification in two or more skeletons. Whichever of these two bones (and it may be either one or the other) is made to assume the functions and connection proper to the thing called clavicle in the human skeleton, will be the clavicle. It is the distinguishing mark of the human clavicle (*a b*, *fig.* 465.), to abut by one end against the sternal piece (*c*), and by the other end (*a*) against the acromion process of the scapula; but, strange to say, we find that both these connections proper to the clavicle of the mammal are divided between the two bones named clavicle and coracoid in the bird. The bone named coracoid (*d*, *fig.* 466.) in the bird joins the sternum (*f*), like the bone named clavicle in the mammal; but it is the bone named clavicle (*a fig.* 466.) in the bird which joins the acromion process (*b*) like the bone named clavicle in the mammal. For this reason, I say, that it is not possible to pronounce what bone in the bird is counterpart of the clavicle in the mammal, since, evidently, those very articular

Fig. 465.



connections which characterise the one bone, called clavicle in the mammal body, are divided

Fig. 466.



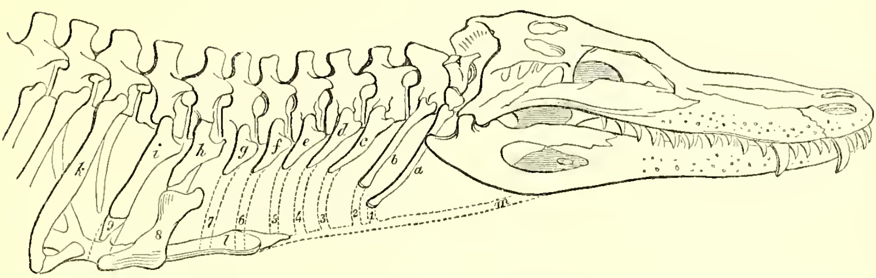
between two bones at the same locality in the bird. It is this circumstance which has given rise to so much written controversy* in the school of comparative anatomy.

I find that the mammal clavicle (*b fig.* 465.) joins the first sternal piece (*c*) by one end

* In the writings of Cuvier, Geoffroy, Carus, Meckel, and others, I find the following statement respecting the identity of the bones called clavicles and coracoids. By one, the furcular bone, at the root of the bird's neck, is accounted the true analogue of the mammal clavicle. By another, this "coracoid" bone, which is behind the furcular, and articulates with the sternum, is called the analogue of the mammal clavicle. By another, this coracoid bone is said to represent the coracoid process of the human scapula. By another, the two bones, furcular and coracoid, are said to be clavicles proper. One states that the corresponding bone, which occurs at the root of the chelonian cervix, is a coracoid bone; another avers that it is the counterpart of the clavicle; another that it may represent either. In the tortoise, the bone is clavicle according to one; coracoid, according to another. In the cassowary and ostrich, where one of the two bones is rudimentary, a doubt arises as to whether this be the coracoid or the clavicle; some prove one reading on the bat, some another on the monotreme, some another on the lizard, others prove their own interpretation on the fish; and Nitsch discovers (?) a small additional rudimentary scapula in the capsular ligament of the shoulder of some accipitres, which he says is proper to the furcular bone, and therefore the furcular bone is a clavicle. I leave the reader to choose his own belief out of these, if it be possible with him.

just as the first thoracic rib (7, 8, *fig.* 465.) itself does; and, in this particular, the clavicle is like the rib. The sternal half of the clavicle (*b fig.* 465.) and the sternal half of the first rib (7, 8) are therefore as identical one with the other as the sternal halves of any other two thoracic ribs of serial order. But I see that while the ribs join the dorsal vertebræ behind, the clavicle joins the acromion process of the scapula laterally. In this latter particular the clavicle differs from the rib. Now, granting this to be a well-marked specific difference between rib and clavicle, I still maintain that there is as broad a difference existing between clavicles of mammals and birds; and also between clavicles and coracoid bones. If change of place at one end from vertebra to acromion process be enough to distinguish clavicle (*a*, *b fig.* 465.) from rib (7, 8) in the mammal body, so must change of place be sufficient to characterise the bone named clavicle (*a fig.* 466.) in the bird from the bone so named in the mammal, for the former does not join the sternum (*f*, *fig.* 466.), and the latter does abut against that bone. And true it is that the bone named coracoid (*d*, *fig* 466.) in the bird joins the sternum (*f*), like a true mammal clavicle, but yet is not considered the clavicle, because its scapular end (*e*) joins another process than the acromion. It appears, therefore, all circumstances considered, that the mammal clavicle (*a*, *b*, *fig.* 465.) is as homologous to the rib (7, 8) in sternal respect (*c*, *d*) as it is to the bird's so-called clavicle (*a*, *fig.* 466.) in scapular respect (*c*, *b*); and at the same time it appears that the coracoid bone (*d*, *fig.* 466.) of the bird is as similar to the mammal clavicle (*a*, *b*, *fig.* 465.), and mammal rib (7, 8) in sternal junction, as the bird's clavicle (*a*, *fig.* 466.) is to the mammal clavicle (*a*, *fig.* 465.) in acromion junction. What, then, is the difference between the rib, the clavicle, and coracoid bone? It is a difference of articular connection, which all three bones appear to share in common,—a crosswise difference in articular connection, which presents us with reasons equally strong for naming either of these bones ribs, as well as clavicles or coracoids. Viewed all three as clavicles, they share the clavicular character amongst them; for that clavicular connection which the one has not, the other has. Viewed as ribs, all three, they share the costal character likewise between them, and hence follows the inquiry into truth; namely, whether their originals be ribs, or bodies absolutely distinct from ribs, passing through metamorphosis. I believe them to be ribs, or costal parts of whole costo-vertebral archetypes, and that their difference depends simply upon that act of the creative force which in the process of development bends them from the continuous line of serial costal order, and renders them cleaving articularly to various parts for the fitness of various special skeletal fabrics. The track of the law of metamorphosis which differences clavicles or coracoid bones from ribs, may be easily followed, if we will enlarge the view, through comparison, and over a sufficient number of facts. As in *fig.* 467. the rib (*k*) follows the rib *i*, 9, in serial order through the thoracic

Fig. 467.



The cervical spine of the Crocodile,

Showing that if in idea we continue the cervical ribs, *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, over the cervix, in the same way as we find the thoracic ribs, *k*, &c., enclosing thoracic space, we then find 8, the clavicle, holding serial order with the costal continuations, 1, 2, 3, 4, 5, 6, 7, which proves the costiform character of the clavicle itself.

region, so does rib *i*, 9, and clavicle 8, taken with the cervical rib *h*, succeed each other in the same serial line; and so likewise in *fig.* 468. does rib *e*, the coracoid *d*, and clavicle *b*, succeed each other in costal order. These bodies are similar by successional position; and the only specific difference between them, upon which we hang the names rib, clavicle, and coracoid bone, is this, viz., that whilst all three bodies have a sternal articulation (*c*, *fig.* 468.), the rib (*e*) still holds connected with its proper vertebral piece, while the clavicle (*b*), and the coracoid bone (*d*) disconnect themselves from their vertebræ behind, and are taken up by the acromion and coracoid processes of the scapula.*

In *fig.* 469. we find the osseous pieces marked 1, 2, 3, 4, 5, to be succeeded by the sternal rib 6, which joins the part *f*, and constitutes the costo-vertebral archetypal quantity of the thorax. If, therefore, the serial order of the osseous pieces *a*, *b*, *c*, *d*, *e*, continued into the

* This fact will be more fully illustrated when I shall have to define the homological relations of the scapulary members.

thoracic rib, invites the reason to name all these pieces as costiform, wherefore should

Fig. 468.

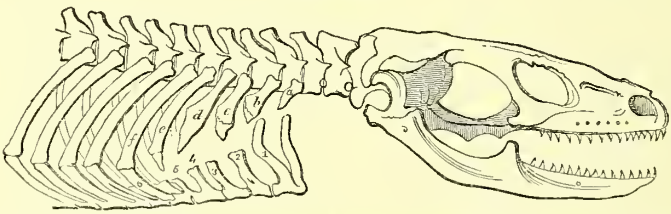
The cervical spine of the Ornithorhynchus,

Showing that *b* the coracoid bone, *d* the clavicle, and *e* the sternal end of the rib, are serial homologues.

we not regard the pieces 1, 2, 3, 4, 5, continued serially into the rib of 6, as being costiform likewise, despite the fact that anatomists have already regarded the pieces 1 and 2 as the coracoid and clavicular bones? Do we not see in *fig.* 469. that the parts 1, 2, 3, 4, 5 point to the parts *a*, *b*, *c*, *d*, *e*, just as the part 6 points to the part *f*? If it be said that the parts 1 and 2 (the coracoid and clavicle), being disconnected from the cervical ribs (*a* and *b*) are therefore to be regarded as quantities unrelated originally to *a*, *b*, I must doubt whether this can efface from the rational mind the belief that the now separated pieces *a*, 1 or *b*, 2, taken as whole quantities, equal the costo-sternal form *f*, 6.

Whether or not the above-mentioned interpretation as to the origin of the bones called clavicle and coracoid be true, must be seen through the facts as they are here recorded: but be this interpretation as it may, I plainly affirm that the comparative anatomist has no positive evidence, near or remote, directly or indirectly, either by a similarity of structure, or function, or position, or aught else, to regard the coracoid process of the human scapula as the counterpart of the bone (*d fig.* 466.) called coracoid in the bird, or of 2, the coracoid of *fig.* 469., the reptile.* The anatomist may just as well call the sternum a series of vertebræ (a statement by-the-by which some have made)*, as to say that there is identity between the human coracoid process and the bird's coracoid bone. However endless may be the whole account of specific difference between bone and bone, and between one skeletal form and another, still there does appear happily some well-marked limits to the homologies. No one, for example, will torture the bone named scapula into an identity of cast with the bone named rib †; and I believe that the same absolute difference is possible to be pointed out between the coracoid process of the human scapula and the bone named coracoid in the bird, or that bone so named in the chelonian reptile. The coracoid process of the human scapula is an elemental part proper to the scapula, just as the centrum is a part proper to the vertebra. The bone called coracoid (*d*, *fig.* 466.) in the bird abuts against that part of the bird's scapula where the coracoid process usually appears in mammal scapulæ; but this coracoid bone is not representative of the mammal coracoid

Fig. 469.



The cervical spine of a Lizard,

In which the cervical ribs, *a*, *b*, *c*, *d*, *e*, point to the coracoid bone 1, the clavicle 2, and the pieces marked 3, 4, 5, as their proper continuations, and just as the sternal rib, 6, continues the vertebral rib, *f*, to the sternal median line.

* On referring to the "Homologies of the Vertebrate Skeleton," I find, in the section "General Homology," the following opinion, advanced respecting the coracoid bone, that it "is always developed from an independent osseous centre (a rudimental representative of the hæmapophysis), which coalesces with the pleurapophysis in mammalia, and only attains its normal proportions completing the arch with the hæmal spine (episternum) in the monotremes." The reader will not, perhaps, comprehend the author's meaning in this sentence, taken separate from the flowing context of the work cited. The meaning of the sentence is this: — The scapulary organ is referred to the occipital vertebra, as the hæmal arch of this segment of the skull, the scapula is interpreted as its pleurapophysis or rib, and the coracoid bone (process) is accounted the hæmapophysis appended to the costiform scapula, and thus the typical occipital vertebra is formed. Although I regard the work from which I have quoted to be a lasting monument of learning, research, and inductive reasoning — a worthy effort in a great cause — still I cannot concur in the opinion which that work announces respecting the relation between the scapulary member and the occipital vertebra.

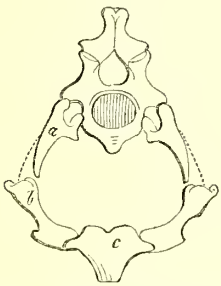
* De Blainville, Meckel, and Carus entertain this opinion, which certainly has no support from natural evidence.

† It is true, however, that this very opinion respecting the scapula is advanced by the distinguished author of the "Homologies," &c.

process produced to sternal junction; and I shall hereafter prove that the coracoid process of the mammal scapula is as distinct a piece from the coracoid bone of the bird, as the centrum of a vertebra is from the costa. In order to understand aright the law of formation, it is as necessary to know what parts are identical and different in two or more skeletons, as it is to know what parts are identical and different in two or more vertebræ; an error in the one or in the other is fatal to a proper understanding of the law which governs the development of both.

While we view the clavicle (*b*, *fig.* 470.) in connection with the cervical rib behind (*a*), we then find that the entire of *fig.* 470. represents a quantity equal to the thoracic archetype, inclosing a visceral or hæmal space ventrad, and a neural space dorsad. This same whole quantity of the archetype is also seen in *fig.* 471., where (*b*) the furculum joins *c*, the sternum, and points dorsad to *a*, the cervical

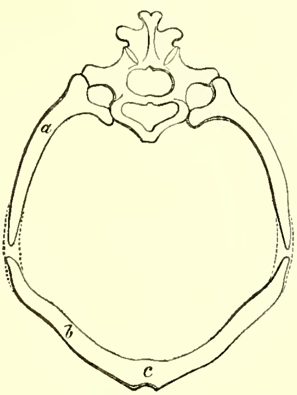
Fig. 470.



The cervical vertebra, with the rib, *a*, the clavicles, *b*, and first sternal piece, *c*, of the crocodile, forming, in their connected totality, the sterno-costo-vertebral whole quantity.

rib of the cervical vertebra. In like manner *fig.* 472. shows the dimensions of a thoracic

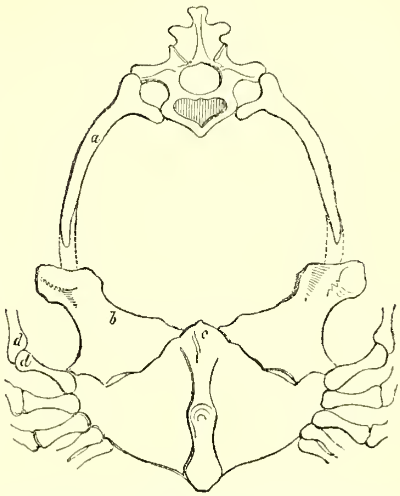
Fig. 471.



The cervical vertebra, with its rib *a*, pointing to the furcular bone *b*, and the sternal junction *c*, which parts in their totality form the sterno-costo-vertebral quantity in the albatross.

whole quantity when we take (*a*) the cervical rib with (*b*) the coracoid bone (so called in the bird) and joining (*c*) the first sternal piece.

Fig. 472.



The cervical vertebra, with the rib *a*, the coracoids *b*, and the first sternal piece *c* of the albatross, forming the whole quantity.

When the whole quantities of the sterno-costo-vertebral circles suffer a dismemberment of their integral parts, then it is that special or diversified objects first appear — then it is that clavicles become special to coracoid bones, and both to ribs — then it is that the anatomists pursue, with special distinctions, fragmental plurality, and lose sight of the intelligible form of unity on the whole.

Osteogenie is constant to the law of serial order. As rib follows rib in serial order—a circumstance which indicates the homological cast of both—so rib, and coracoid, and clavicle, which take serial order, indicate by this same fact their own identity or homological relation. But the mammal's coracoid process is a part distinct from the bird's costiform coracoid bone. The former never takes place of the latter, but is a part proper to the scapula alone.*

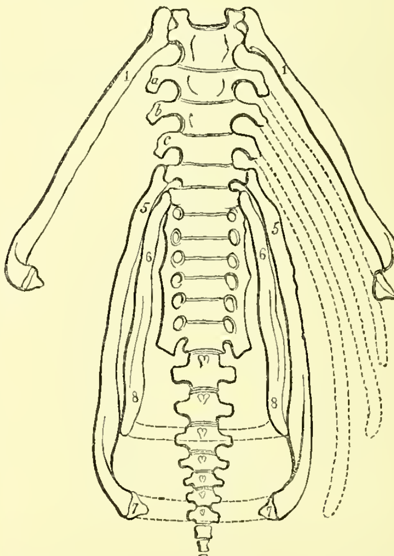
* Professor Owen's idea of the relationship of the mammal scapulary member and its coracoid element to the occipital vertebra, must imply that the coracoid clavicle of the bird is (if the mammal coracoid process and the bird's coracoid bone be considered by him to be homologous parts) also referable to the occipital vertebra. This homological relation, I am bound to say, I could never discover; and if the asserted relationship between these parts shall be ever received as an opinion true to nature, the learned author is certainly the discoverer. For my own part, however, I must confess myself no convert to the belief that so large an amount of displacement between any two numbers of a whole quantity, such as that which, according to the author, is instanced in the totality of the occipital vertebra, taken with the scapulary limb, ever occurs, but I am rather impressed with the opinion which the immortal Goethe advanced respecting the fixity of place which osseous pieces of the endo-skeleton invariably hold: "L'ostéogénie est constante, en ce qu'une même os est toujours à la même place." Œuv. d'Hist. Nat. p. 41.

While clavicles, coracoid bones, and ribs appear identical, we then can readily understand how a bird or reptile may possess two or more clavicles, according as the laws of form shall subject two or more of the original costæ to clavicular modification. The clavicles, therefore, of the mammal and the clavicles and coracoids of the bird or reptile being costal quantities under metamorphosis, these bodies are to be regarded as the ribs proper to those cervical vertebræ, opposite to which they appear in all skeletal forms.*

Prop. XXXV. *Marsupial bones, pubic and ischiadic bones, and ribs, are identical parts of the costo-vertebral whole quantities or archetypes.* — Wherever we find these parts, viz. sternum, rib, and vertebral piece, occurring in skeletal fabrics, we shall never find that they take the place of each other. The sternum, even when appearing isolated from the other parts, is still holding its proper locality at the median line in front. The rib is always found laterally, and the vertebral piece always behind. The sternal pieces hold serial order, and hence we know them throughout all variety of modification. The costæ in like manner hold serial order, and hence we also recognise these parts. The vertebral pieces hold their own serial order, and thus we know them. The costal, the sternal, and the vertebral serial orders are never interrupted by the introduction of a new and unknown element among the bodies which form each serial line. There never occurs among the vertebral pieces behind any other thing which by being difform to vertebræ, may disconnect that vertebral series. The same remarks apply to the sternal bodies in front, and the same to the costal pieces arranged laterally. Every body which holds serial order with the sternal bone is a sternal bone, and constituting sternal serial order. Every body which holds serial order with a vertebral bone is a vertebral bone, and constituting vertebral order. Every body, also, which takes serial order with a rib is a rib, and constitutes costal-serial order. Every body, therefore, which on first sight shall seem to be specifically distinct from that order with which it holds series, is in fact only rendered special in such order by modification; originally it is identical with all the pieces of that same order.

Just as the clavicle and coracoid bone hold series with ribs, and are ribs originally, but rendered special by modification, so does it appear that the marsupial, the pubic, and ischiadic bones, which hold serial order with ribs are ribs originally, but now presenting in such conditions of modification as we mark by nomenclateric difference. A clavicle, a coracoid bone, a marsupial bone, a pubic bone, and an ischiadic bone, are thus differently named in order to point to their several specialities of caste. But through these special characters their costiform original character is still visible, and therefore I call them ribs modified. These modifications which clavicles, coracoids, marsupial, pubic, and ischiadic bones present, when contrasted with each other and with ribs, are in reality of no greater amount than those varieties which are apparent among those bodies which we name ribs, enduring as such through the skeletal axis. At the present day we well know that the thing named rib is not necessarily confined to that region of the skeletal axis named thorax. Ribs are found embracing the ventral region of fishes, and all spinal regions of ophidians. Ribs of unequivocal character are also developed embracing the venter of Saurians. Ribs are jutting out laterally from the loins of the draco volans, supporting the parachute of that animal. In fact we can readily distinguish the costal character of many bones, even though they are separated from their proper vertebral centres behind. See these osseous quantities, which project from the sternal bone behind, ensheathing the venter of the bird's, and the Saurian's skeleton, and standing free from the lumbar vertebral pieces, to which, nevertheless, they refer,—are they not ribs, which special laws have dissevered from the spinal axis behind? It is not, therefore, necessary to the bone named costa, that it should always hold attached to the vertebral form posteriorly, and to the sternal form anteriorly. And why, therefore, not extend the name costa to those

Fig. 473.



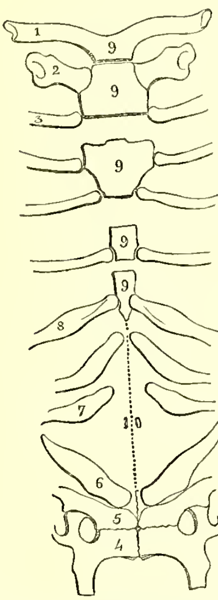
osseous parts which do not present greater varieties compared to ribs, than ribs do when compared to each other. The law of serial

* The same reasoning which leads the author of the "Homologies" to refer the coraco-scapular arch to the occipital vertebra, induces him to pronounce the mammal clavicle to be naturally related to the atlas vertebra. Now, I cannot understand why the author's views, which are certainly correct, in so far as he is led to believe the pair of clavicles to be the inferior arch of some one of the cervical vertebræ, should make choice of the atlas so remote, in preference to that cervical vertebra, opposite which the clavicles appear.

order must indicate the true character of those osseous parts, whose various names serve to blind us to the actuality of their homologous caste. Examine closely the anatomical fact, and see whether I am stretching the imaginative faculty while I assert that the pubic (5,7) and ischiadic bones (6, 8) of the bird (*fig.* 473. ostrich) are actually springing from the lumbar vertebræ like true ribs, (1. of the thorax). If, therefore, it be the rule to affirm as incontestible truth that these pubic and ischiadic bones of the bird are counterparts of the bones so named in the mammal, wherefore should we stop here, and hesitate to name both orders of bones (those of the mammal as well as of the bird) as ribs originally?

Even up to the present hour we find the osteologist strolling the Museum, and still marvelling at the interrogative marsupial bone (6, *fig.* 474.). What is it? Whence is

Fig. 474.



The thoracic and ventral median line of the Ornithorhynchus,

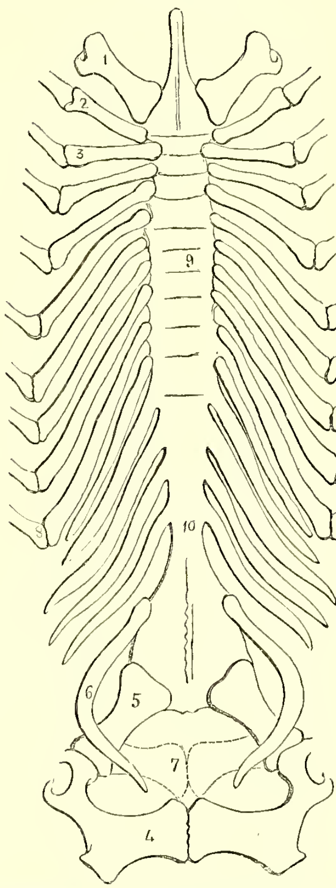
Showing the serial homology between the coracoid bones (2), clavicles (1), ribs (3), and the marsupial (6) and pubic bones (5).

it? What is its interpretation? What else, I answer, can it be, but a ventral rib, proper to some one of the lumbar vertebræ behind. If in these pages I have furnished the querist with the idea that a lumbar vertebra has lost costo-sternal quantity, then he cannot be unproductive of the idea, that this marsupial bone, which now occupies the place of this costal quantity of the lumbar vertebra, is none other than this quantity itself. Besides this, it is also evident, from the serial order which the marsupial bone (6, *fig.* 474.) holds with the line of costæ (3, 8, 7), that it is itself costiform.

Now, in *fig.* 474., it will be also seen that the pubic bone (5), and the ischiadic bone (4), hold series with the marsupial bone (6), just as this latter holds series with the ribs (7, 8.) Does not this serial order prove the identity of all these bodies in common? Do they not all alike abut against their symmetrical fellows at the common median line? Does not the pubic bone exactly correspond with the sternal median line?

In *fig.* 475., representing the continuous series of costiform bodies from the clavicles

Fig. 475.



The thoracic and ventral median line of the Crocodile (dorsal aspect),

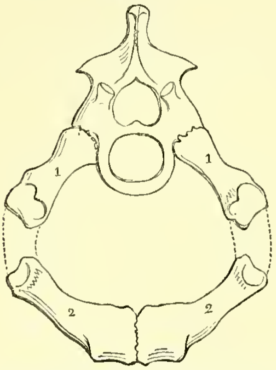
Showing the same serial order of the parts named in *fig.* 474.

(1) to the ischiadic bones (4), it is scarcely possible to recognise a difference between all forms of this serial order. The clavicles (1) are succeeded by the ribs (2, 3, 8), these by the ventral ribs from (8 to 6), and these by the pubic bone (5), and the ischiadic bone (4). The homology between the bodies, (1) the clavicle, and (2) the rib, is as clearly apparent as between (5) the pubic bone, and (4) the ischiadic bone. Moreover, the homology between (1 and 2), (5 and 4), is as clearly apparent as between any two ribs of the series. If (5) the pubic bone still held its original place at (7), and had not disconnected itself from the ischiadic bone (4), it

would not be more like the clavicle (1) than it is in its present situation.

In *fig.* 476., the pubic bone (2) occurs opposite to the sacral vertebral rib (1), and the

Fig. 476.

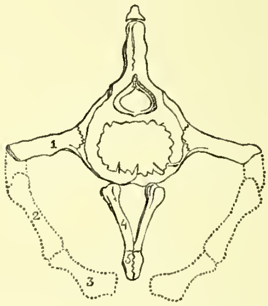


The sacral vertebræ and pubic forms of the Crocodile, forming the whole quantity.

whole form is thereby completed as the sterno-costo-vertebral-archetypal quantity. The part 2, of *fig.* 476., may, therefore, as appropriately be termed a pubic rib as a costiform pubis. This pubic bone (2, *fig.* 476.) is separated from the sacral rib by an interval equal to the iliac bone, and this latter is regarded by a high authority * to be of costiform character; but in the present reading I have no need to view the bone in this regard.

Prop. XXXVI. *Chevron bones and ribs are identical parts of the costo-vertebral whole quantities or archetypes.* — As every part which shall appear plus upon a cervical or lumbar vertebra, such as cervical or lumbar ribs, may be referred to the original whole quantities from which the cervical or lumbar vertebræ have been metamorphosed, and gain their proper interpretation accordingly, so may those parts which now and then appear plus upon the caudal vertebræ, such as "chevron bones" (4, of *fig.* 477.), be likewise referred to the original whole quantities from which those caudal vertebræ have been degraded. We have seen reason to interpret the caudal bone as the centrum of the vertebra, — of which vertebra? Of the thoracic plus vertebra; for why not of this plus archetypal form, as well as of any other form less in quantity than this archetype? If the caudal bone be considered as a part degraded from the equal of the lumbar vertebra, why not also from the equal of the thoracic costo-vertebral archetype? If the caudal bone gives evidence of the fact that its present condition is owing to the loss of the

Fig. 477.

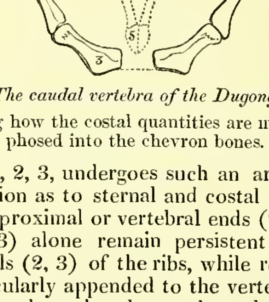


The caudal vertebra of the Dugong,

Showing that it is not the typical or whole vertebral quantity.

neural arch, the spinous process, and transverse-costal processes, and if it elicits accordingly the interpretation that had those elemental quantities still persisted, that which is now the caudal would have been equal to the lumbar vertebra; so, on the like grounds, we may elevate ourselves to the reading, that if the thoracic ribs and sternum, the neural arch and spine still persisted, that which is now the caudal bone would have been equal to the thoracic archetype. Such a reading I here venture to put forth respecting the caudal bones (*fig.* 477.), and when these develope the chevron ossicles (4), I interpret them as being proximal parts of the costal arch (1, 2, 3), left standing after the degradation of the whole archetypal quantities. If a thoracic costo-vertebral archetype, such as *fig.* 478., whose costal

Fig. 478.



The caudal vertebra of the Dugong,

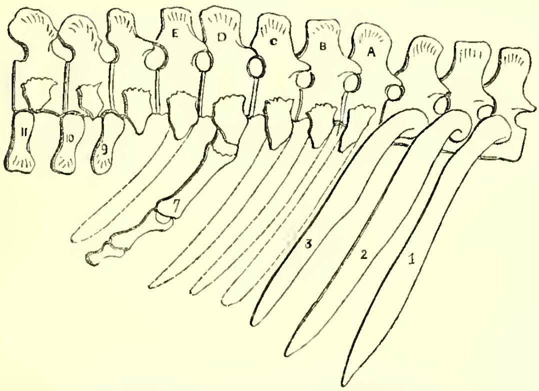
Showing how the costal quantities are metamorphosed into the chevron bones.

arch is 1, 2, 3, undergoes such an amount of degradation as to sternal and costal quantity, that the proximal or vertebral ends (2) of the ribs (2, 3) alone remain persistent; and if these ends (2, 3) of the ribs, while remaining still articularly appended to the vertebræ, are bent towards each other and to the median line, taking the place of the parts 4, 5, then

* The author of the "Homologies" entertains the opinion that the iliac bones are the "pleurapophyseal" (costal) elements of the sacral vertebra, and thereby he connects the pubic arches (his hæmapophyses) with their proper vertebral pieces in the sacrum. This opinion as to the costiform character of the ilium or haunch bone, is by no means that which I hold respecting it, nor can I believe that any other anatomist will discover the similitude between an iliac bone and a rib, any more than between a scapula and a rib, or any more than they will find to exist between a sternal piece and a spinal vertebral form, even though the imposing names of Oken, Meckel, and De Blainville introduce this latter opinion.

we shall have produced such a vertebra as *fig.* 477. or 478., which, composed of the elements 1, 4, 5, happens in the tail of cetaceans, saurians, fishes, and many species of even the quadruped mammalia. There are chevron ossicles developed on the caudal vertebræ of the quadrumanous species. The caudal vertebra (*fig.* 477.) having the chevron bones (4) and inferior spinous process (5) appended to it, is taken to be the typical vertebra by all anatomists. They regard it as containing all the elemental parts proper to all vertebræ, an opinion, the error of which I shall not here stay to point out, if it be not already demonstrated by what I have elsewhere spoken. Taken as quantities of osseous form, it would be as impossible to distinguish the same parts in such a "typical" vertebra, as either 9, 10, or 11, *fig.* 479., and that which stands at the thoracic region of spinal series, as it would be to read the quantity $a-b$ and $a+b$ as equal. In *fig.* 479., which represents the cetacean loins, it will be seen that the thoracic ribs 1, 2, 3, hold serial order

Fig. 479.



The lumbar region of the Dugong's skeleton,
Showing a serial degradation of the ribs into the chevron bones.

with the costiform pubic arch 7, and that this series is continued into the lesser quantities of chevron bones 9, 10, 11. This serial order indicates the homology of these several structures.

Prop. XXXVII. *The sternal median line ranges from the maxilla to the pubic bones of the abstract archetypal skeletal fabric.* — In order to comprehend the truth of this proposition, the reader will have to exercise his mental as well as his bodily vision. He will have to expand his view over a large number of facts, and to compare these one with another, and sum together all the evidences, making them demonstrate the generalization which I here propose to establish. The abstract idea which general comparison has furnished me with respecting the sternal median series of osseous pieces, I shall endeavour to develope in the reader's mind, after the same manner in which it was furnished to my own; and comparison of anatomical facts shall be my instrument.

When I compare all skeletal fabrics by the sternal apparatus, I find that such an infinite variety marks them in respect to this particular, that it would take a long and busy lifetime to make a record of one half of those varieties; and, after all, it is most true, that such record would not be worth one jot to science, since it would leave us in the end no better informed as to the law producing this variety, than when we first began. The one great fact which I shall remark upon in reference to the sternal apparatus is, that it is a part which varies not only in several species but even in the one species, and that it is a structure the most indeterminate and indefinable of all those constituting the osseous skeleton. It is produced of variable lengths in the human body, and in every other animal species regarded *per se*.

Now, assuming that the interpretation of sternal variety, and not the enumeration of it, is the sovereign and paramount object of comparative research, I here venture to affirm, that there is no other mode of accounting for this variety, as it appears already created, or of interpreting the process which has yielded it, excepting that of regarding every variety of sternal apparatus as being proportional lengths cut from a whole linear sternal quantity, drawn in continuous order through the median line of the fore aspect of the animal fabric from end to end. The reasons which lead me to adopt this reading of the source of sternal variety are as follow.

When I examine the human skeleton as a form isolated from all other forms of the four higher classes of animals, I find the sternal series of osseous pieces extending through that region of the median line in front where the fully produced ribs meet it and enclose thoracic space completely. This costo-sternal junction happens generally between the seven first ribs and the sternal apparatus. It is owing to this sternal union of these seven ribs, that the human anatomist terms them "true ribs." The five succeeding costal pairs he terms "false ribs," because they are

asternal, that is to say, falling short of sternal junction. A comparison held between these seven sternal and five asternal ribs, must lead the reason to draw the conclusion that the difference between both orders of these ribs is caused by the subtraction of a certain osseous quantity from the asternal ribs, which circumstance has dissevered them from the sternal median line; and hence follows the relationary inference, that if this osseous quantity had not suffered subtraction or metamorphosis from those ribs which are now in asternal character, these would have persisted in their original archetypal or plus quantities, and would thereby have joined a sternal median line, just in the same way as the seven true ribs still do. In this case, we should have had twelve true or sternal ribs forming the human thoracic cavity. In the same way, again, I may remark, that if the five ribs which are now lost to the lumbar vertebræ, and which loss has rendered these bodies in the lumbar fashion, had still persisted in their original archetypal proportions, these ribs would also have joined a sternal median line, and would have thereby completely enclosed ventral space. In such case we should have had seventeen true or sternal ribs. Again, if the original or archetypal costo-vertebral osseous quantities, from which the sacro-caudal series of vertebræ have been metamorphosed, had still persisted, these also should have joined a sternal median line, and completely enclosed space. In this case we should have had twenty-eight true or sternal ribs. And if the original archetypal osseous quantities, from which the seven cervical vertebræ have been metamorphosed, had also still persisted, we should then have had thirty-five true or sternal ribs. In which case the human skeletal axis, instead of numbering, as it does, thirty-five spinal segments of variable proportions, such as those of cervix, thorax, loins, sacrum, and caudex, would have presented to us, in its original or archetypal quantity, the number of thirty-five sternal costo-vertebral spinal segments. In such a form, I imagine that the sternal median line would range from one extremity to the other of the serial spinal axis. And now let us examine, whether this ideal archetype coincides with all natural evidence derivable from general comparison.

Not only does a numerical variation occur in human species as to the true or sternal ribs (for I have seen them counting from 7 to 10), but I will venture to predict, that we should find this numerical variation, as to sternal ribs, happening amongst the individuals of any other species of the four classes, if we dissected them as frequently, and with as much interest, as we do the human body. In the human skeletal form, we are accustomed to name the seven sternal ribs as normal to this type; and all excess of costo-sternal union as abnormal or anomalous. The like variation, from normal to abnormal, occurs amongst the individuals of every known species of skeleton; and the reason which I assign for this variety of infinite account is, that all such variety, whether normal or abnormal, is but a minus condition, degraded from a plus or archetype condition of skeletal form, which latter has all the vertebral pieces holding homologous series behind, all the costal pieces holding homologous series laterally, and all the sternal pieces holding their own order anteriorly. In such an archetypal skeleton there could be no such hiatuses or gaps, in series, as those of the cervix and the venter, &c., where, be it remembered, all variety and "anomalous" creation occurs.

Now is there not every good reason to believe that the contrast, which the normal condition of any one species bears to the abnormal condition of that same species in respect to the number of ribs meeting at a sternal median line, is only a part of that general contrastive condition which all species bear to one another, in respect to this same costo-sternal union or non-union? Let us examine this truly marvellous law, whereby all contrasts of formation result, not only for the one species, but for all species: for it is this law which I conceive to be the proper aim of the osteologist. Let us not weary patience with recounting the facts that skeletal forms *do* differ, but let us rather furnish imagination with the one over-arching fact, as to *how* they are differenced, each one to each, and all to archetypal uniformity.

All individuals of one species will, when viewed collectively, manifest the normal and abnormal contrasts to that same species, in respect to variation in the number of sternal, and the number of asternal ribs. All species, viewed collectively, will manifest the same, only in a greater degree, and in broader contrast. When I compare the normal and the abnormal conditions of costo-sternal union in individuals of the same species, and also the numerical variety as to the number of sternal and asternal ribs, I find that the abnormal is to the normal condition of the one species, nothing more than what the normal condition of one species is to the normal condition of another; hence, I say that it is the same law which produces, in the one case, the normal and abnormal castes of form in the one species, and the normal castes of form in diverse species. If one human skeleton differs from another, as to the number of sternal ribs and of asternal ribs, and that in one we find the cervical ribs, in another the lumbar ribs, and in all some number of ribs or other, what is this variety, and whence has it occurred, but by the operation of that same law of metamorphosis which fashions the skeletal axis of a baboon of one number of ribs, that of a horse of another number, that of a sloth of another number, that of a cetacean of another number, that of a bird of another number, that of a reptile of another number, that of a fish of another number? Is it not this same law which has fashioned all individual species of mammals of variable numbers of ribs? all individual species of birds of variable numbers of ribs? all individual species of reptiles of

variable numbers of ribs? all individual species of fishes of variable numbers of ribs also? Is not numerical difference, as to costal, as to vertebral, and as to sternal elements, infinite? Where, then, shall we find a resting place in this ever moving creativeness of the variety? There is no resting place for the understanding, except in the idea of the skeletal archetypal uniformity, and there is no other mode whereby to mount to the recognition of this archetype, but by summing together all proportional variety, and constructing plus uniformity from out of it.

The number of osseous thoracic sternal pieces varies even in the same species; it varies still more in the different species of a class, and general comparison carried through the four classes will prove incontestibly, that the region which is ventral, or minus the osseous ribs and sternum, in one animal (the human), is furnished with the ribs and sternum in another animal (the saurian), and hence becomes thoracic for this latter animal. In the mammal venter, the costo-sternal osseous pieces do not exist, but in the saurian venter they do. In the same way will general comparison prove that the region which is cervical, or minus the ribs and sternum, in one animal, is furnished with the ribs and sternum in another animal, and hence becomes thoracic for this latter animal. In the mammal cervix, the costo-sternal osseous pieces do not exist as such, but in the ophidian and the fish they do; for what else is the fish's hyoid apparatus but a series of ribs joining a sternal series?

Now, the true interpretation of the individual skeletal fabric is only to be had in the abstract or compound idea which springs from general comparison. The abstract or archetypal skeleton is the exponent of the special or individual skeletal fabric. The former is plus quantity, the latter is a special creation degraded from such a plus.

The thoracic sternal series of the human skeleton commences, as bone, at the junction of the first pair of thoracic ribs, and continues as bone as far as the junction of the seventh pair of ribs; after this latter point the human sternum degenerates into cartilaginous or primordial tissue of the second stage of ossific process, and from thence it is continued over the ventral region in fibrous or primordial tissue of the first stage of ossification, and as such is united to the pubic symphysis, thus relating this point to the thoracic sternum, and also the pubic and ischiadic bones to the thoracic ribs, with which they are identical, no doubt. Those fibrous bands, named "lineæ transversæ" of the human venter, must be taken as sketches drawn in primordial substance by the hand of nature, indicative of the ribs which are wanting at this region of series. Those ribs are proper to the lumbar vertebræ. The linea alba is a sternal trace of archetypal osseous quantity, and is proper to the ribs which are now wanting at the mammal venter. The saurian venter, furnished as it is with both sternum and ribs, and lumbar vertebræ, must therefore be regarded as a nearer approach to archetypal or thoracic uniformity than the mammal venter. In the former, the ventral region is embraced with an osseous costo-vertebral sternal apparatus, like the thorax. In the latter, the ventral region presents this apparatus degenerated into primordial or fibrous bands. The original of the mammal venter is thoracic, and, as such, I affirm that this original, although now only in idea, stands before the mental vision in as vivid a character as if its actual presence presented to the corporal vision. That which is wanting at the venter of the mammal is equal to that which is persistent at the venter of the saurian; and thus, in idea, I draw the sternal and costal osseous series over the ventral region of the mammal body. In every skeletal fabric where a venter is formed without the sternum and the ribs, nature may be said to have subtracted these for fitness and functional ease.

The law of species requires that the costo-sternal series should not persist in the ventral and cervical regions of all animals, the reasons for which are obvious. It is by this law of special or proportional variety, which creates the cervix and the venter as fitting hiatuses in series, that the law of archetypal uniformity becomes eternally interrupted. The law of species is acting in constant nisus opposed to the law of plus quantitative uniformity. Both laws are eternal, and their eternal acts yield forms as they are. viz. a *unity in variety*; that is to say, a whole quantity undergoing a metamorphosis of parts. It is this metamorphosis or subtraction of parts proper to the whole archetypal quantity, which furnishes all the endless sum of variety.

The "xyphoid" cartilage and the "manubrium sterni" are the opposite extremities of sternal series in the mammal skeleton. At these extremities there is manifested, as it were, a constant tension or endeavour to extend the sternal line over the neck and abdomen. In the mammal body and others, this tendency to extend is held in constant subjection; but occasionally we find that this nisus of the creative force advances a step, and marks its progress by the development of "episternal ossicles" at one end of the sternal line, and by additional nuclei of osseous substance at the other end. The character of either extremity of the sternal series is unfinished; and even amongst the individuals of the several species of mammalia and birds, it cannot be said to be fixed. Sternal creation, and the law of its infinite variety as to length, can only be fully ascertained by extending the observation through general comparison. In general comparison, we readily discern the ability of creative force exercising itself by the simple addition and subtraction of certain known elemental parts. By the addition of parts, nature mounts to archetypal uniformity; by the subtraction of parts she degrades to variety. Every variety is but a submultiple of archetypal uniformity.

When I limit my observation to the individual mammal skeletal form, I find the

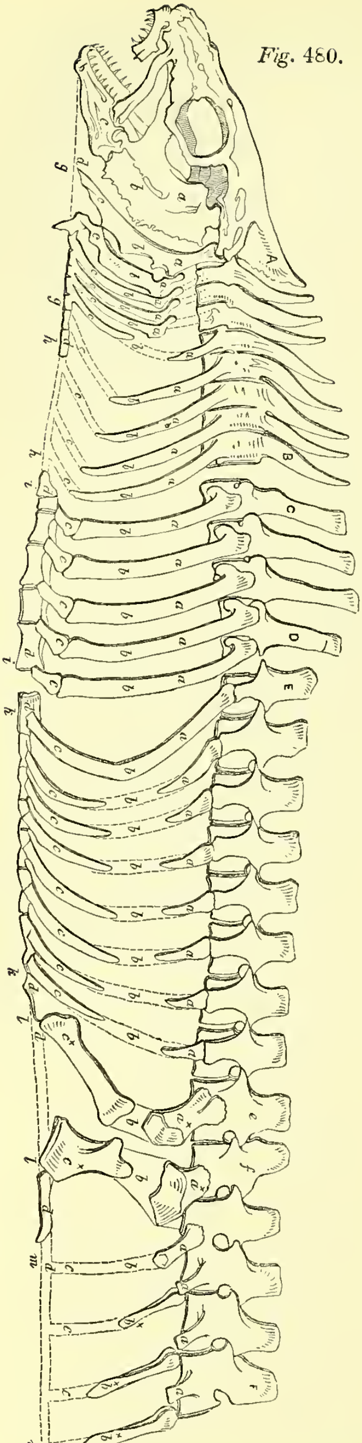


Fig. 480.

An archetypal skeltal axis, constructed of the Piscean cervix, the Mammalian thorax, and the Reptilian venter and caudex,
Showing the original serial continuity of the ribs and sternal median line.

osseous sternal median line produced for the most part of set dimensions; but when I extend my comparison through all individuals of that class, I find the sternum to be created of variable length, and constituted of variable numbers of elemental pieces. When, further, I carry my observations through all individuals of the four classes, fishes, reptiles, birds, and mammals, I find that the osseous sternal median line has no limit short of the space which the maxillæ mark before, and the pubic arches behind. Hence it is that I call every sternal apparatus, which happens to be created of lesser dimensions than this space, as a specialty cut from the transcendent line of sternal median uniformity, such as *fig.* 480. represents, with the piscean neck A B, the mammal thorax C D, and the reptilian venter and loins E F. Now, the hyoid apparatus (a, b, c, d) occurs at the median line of the cervix (A B, *fig.* 480) where we know costal quantity to be subtracted. The costo-sternal apparatus (a, b, c, d) happens at the median line of the thorax (C D), where we still view costal quantity persisting. Let these two facts be submitted to the focal light of comparison, and I doubt not but that reason must draw the conclusion, that as the ventral sternum ($k\,k$) relates the pubic symphysis ($c*\ d$) to the thoracic sternum (i, i), so does the hyoid sternum as a cervical sternum (g, h) relate the maxillary symphysis to the thoracic sternum (i, i). Hyoid apparatus is, therefore, but a name by which we designate the degree of metamorphosis to which the original costo-sternal series of a cervix has been subjected. It is this metamorphosis which has rendered the costo-sternal quantities, proper to the cervical vertebræ, into the vocal organs of one class of animals, into the laryngeal organs of all animals, and into the branchial organs of the fish (A B), in which latter class the character of the original costo-sternal apparatus is least modified; for evidently the hyoid or branchial apparatus (a, b, c, d) of the fish (A B) is constituted like the thoracic apparatus (a, b, c, d) of other animals (C D), of a series of ribs joining a sternal median line.

The greater the degree of metamorphosis which the archetype has undergone, the greater is the obscurity of that structural analogy existing between organs of the same order in two or more animals.

But though we are accustomed to limit the name sternum as applicable alone to the *osseous* part of the common and general median line of the mammalian animal, and though we do not usually recognise as a sternum in this class that region of the median line which presents in cartilaginous structure, as, for example, at the neck and venter, still I maintain that, so long as it is acknowledged that comparison is the only instrument by which we can ever hope to ascertain the law of formation in the creation of special differences, we must interpret the linea alba as being the continuation of the sternal line in the mammal abdomen, and the cricoid, the thyroid, and

hyoid forms, whether these be cartilaginous or osseous, as being the continuation of the sternal median line in the mammal neck.

The history of the ossific process teaches us that every part of the skeleton which presents now in osseous structure, has passed through the prior stages of cartilage and of fibrous or cellular primordium. The general median line in front of the mammal form presents, in regional divisions, the one differenced from the other only in respect to these three stages of the ossific process. The thoracic sternal median division presents in the tertiary or osseous stage. The cervical sternal median division of this same line presents in cartilaginous or secondary stage. The ventral sternal median division of this same continuous line presents in the fibrous or primary stage. But whether the several divisions of this one sternal median line be, in the mammal body, of fibrous, or cartilaginous, or osseous tissue, it must still be regarded as the same unbroken sternal series from maxilla to pubis. The only difference which marks one class or species of skeletal form as distinct from another throughout the animal kingdom, is simply the same as that which marks one region of the sternal line in one form diverse, or special, to another region of the same line in the same form. What the ventral or the cervical sternal median line is to the thoracic of the same animal, namely phasially different; just so is the ventral and the cervical median line of the several classes and species of animals diverse to the thoracic of all animals by a simple arrest of development in one or other of the three phases of the ossific process. The venter of a mammal is intersected with fibrous traces of the sternum and ribs. This sternum and these ribs are of osseous growth in the saurian venter (*k*, *k*, *fig.* 480.). The cervix of a mammal is intersected with the cartilaginous and osseous traces of original sternum and ribs, and these traces of the sternum and ribs are now called hyoid apparatus. The homologue of this hyoid apparatus, which is fashioned by the metamorphosis of sternum and ribs, is presented in the osseous fish (*g*, *fig.* 480.) as a sternum and ribs, to which we give the name hyoid apparatus.

When I compare the foregoing anatomical facts together, I conclude that the abstract or archetypal skeletal fabric (*fig.* 480.) to which comparison gives creation in my mind, is a form whose median sternal line is continuous from maxilla to pubis, from g to *l*, and in this archetype the ribs (*a b*) are holding continuous series. The vertebræ (A B, C D, E F) hold serial order in the same archetype also. The ribs succeed the hyoid apparatus, the pubic and ischiatic bones (c^*e^*) succeed the ribs, and the chevron bones (b^*b^*) succeed the pubic bones. This serial order demonstrates the homological cast of all these parts, and therefore I have numbered them alike. When these serial parts are taken in connection with the vertebræ behind, they constitute the archetypal series of whole quantities.

Prop. XXXVIII. *Every fossil skeletal species of extinct animals, as well as every recent existing species of skeleton, are forms created of the archetypal skeleton.* — While we understand clearly, that it is the graduated metamorphosis of certain parts from one or many of the serial sterno-costo vertebral archetypes which yields all spinal axes, variable as to the numerical lengths of a cervical, or a lumbar, a sacral or a caudal region, and while we know, even to a demonstration, that the thoracic region results simply by the persistence of some of those archetypes, then we can readily understand that the persistence of all the archetypal quantities would leave the form devoid of any such regional spinal variety as a neck, a loins or a caudex. And when I add to this remark this other, namely, that all the archetypes undergoing cervical metamorphosis would render all the spinal length in cervical character, or, if undergoing lumber metamorphosis, would strike the whole spinal length in lumbar character, or if submitted to sacral or caudal metamorphosis would leave the whole spinal length of sacral or caudal stamp, then I see no reason why anatomical science should marvel at the length of a plesiosaure neck as an extraordinary fact " dug out of the bowels of the harmless earth," however bizarre a creation this skeletal form may seem to the wonder-working geological speculator.

Forms, as they are at present existing, and congeneric, seem to me to manifest, under contrast, no less a cause for wonder while I view them comparatively, than these same existing species of form can give rise to when I regard them comparatively with those of the lost or extinct species of a foregone time. But I believe that the only hope which science can ever entertain of solving the problem of formation in the past, must depend upon the demonstration of the process of the creative force, which rules formation in the present And when we shall have clearly demonstrated the creative law which at present strikes out the form of an ostrich in presence of the form of a whale, then we will cease to regard with doubtful interrogative the form of the Plesiosaure laid side by side with the Ichthyosaure, or any other figure the vestige of foregone creation. When science shall arm herself cap-a-pie with the knowledge of a law, then will she be enabled to contemplate the past, the present, and the future, holding her statuesque gravity still unmoved, however or by whatever show of seeming bizarre facts short-sighted ignorance may strive to startle her.

Upon the proof of the truth of the reading here advanced, viz. that the cervical the lumbar, sacral, and caudal spinal regions consist of spinal segments metamorphosed or degraded from such archetypal segments as we find standing for the thoracic spinal region of all skeletons, depends the full and just interpretation of all varieties of spinal axes of animals, whether now existing or now extinct.

Prop. XXXIX. *The cranio-facial apparatus consists, like the thoracic apparatus, of*

variable proportionals of the sterno-costo-vertebral quantities.—The connection which exists between the cranial and the facial structures is quite as intimate as the connection which exists between dorsal vertebræ and thoracic ribs. In nature, we never find the cranial structures happening independent of the facial apparatus; but we invariably witness the presence of both, whenever the presence of one is manifested, just as is the case with dorsal vertebræ and the costal apparatus; and therefore it is that when I shall presently draw comparison between cephalic and thoracic regions of the spinal serial axis, I shall regard the one as a cranio-facial series of osseous quantities, homologous to the other as a costo-vertebral series.

Before I proceed to compare the cranio-facial apparatus with the thoracic costo-vertebral apparatus, let me here distinctly state one or two positions, which I shall not engage to define, simply because it would be impossible to prove that certain conditions were manifested, which are in fact and nature not manifest. *Firstly*, I do not mean to shew that an equality or quantitative uniformity characterises the cephalic and the thoracic regions of the one spinal series; nor, *secondly*, that all species of cephalic apparatus of the four classes are constituted of absolutely equal quantitative structure*, any more than thoracic apparatus are themselves; nor, *thirdly*, that the number of cranio-facial segments and the number of costo-vertebral segments correspond in the same spinal axis; nor, *fourthly*, that the number of cranio-facial segments correspond in the cephalic apparatus of all animals of the four classes, any more than the thoracic apparatus of the same animals correspond as to the number of spinal costo-vertebral segments.

The so-called "vertebral theory" appears to me to have played lightly with the serious patience of anatomical science, and to have brought itself into discredit, not because it has proved no one truth in generalisation at all, but because it has striven, while standing upon equivocal and unproven grounds, to demonstrate that which had existence no where save in the imagination. An ill-defined shadowy resemblance was first seen to have existence between cranial and spinal vertebral forms, and in pursuance of this idea has arisen all that vagrant and bizarre imagery which has enveloped the first dawn of a great truth in the smoke and mist of that sacrifice and homage which it was thought was due to the inspired genius of him* who first promulgated it. I shall not here trouble either the reader or myself with a barren discussion about the merits or demerits of the views of those authors who sought to expand this vertebral theory beyond its natural limits, or of those who strove to discountenance the theory altogether, rather than to pursue it to the verge of sheer nonsense. My present limits confine me to the observation of nature, and will not suffer me to canvass written opinion concerning her to any greater extent than such opinion shall be confirmed as corresponding with natural truth. Out of all that loose and flighty imagery which anatomists of the transcendental school have indulged in, I select the first and only truth which has ever been fairly established, viz. that one respecting the homology between cranial and vertebral structures. That this homology exists between the osseous envelope of the cerebral mass and the osseous coverings of the spinal chord, is now a fixed and immoveable fact in anatomical science. But though the existence of this homology is now undeniable, still I may remark that every observation which serves to prove something further in respect to spinal vertebræ, which had not been known previously to the recognition of this cranio-spinal resemblance, must also prove that the same thing was unknown respecting cranial vertebræ. Every new fact, established upon the comparison of spinal vertebræ, must be new also in regard to cranial vertebræ; and this is the

* Almost all the anatomists of the French and German schools differ in opinion as to the number of modified vertebræ which compose the head, for while some of them limit the number to three, viz. those which enclose the encephalon, others count as many as seven; and these latter have increased the number by absurdly likening the facial structures to the vertebral forms also. Goethe counts six, three of which comprise the cranium, the other three the face. Oken enumerates four; Spix, three; Cuvier, three; Geoffroy, seven; Carus, three (Lehrbuch der Zootomie); Meckel, three (Beiträge zur vergleichenden Anatomie, Band II. S. 74.); Bojanus admits four, and Burdach only three. Professor Owen enumerates four in the fish, the reptile, the bird, and the mammal. See "Homologies," &c.

* Oken is generally acknowledged as the signal discoverer of the homology between cranial and spinal segments. He believed that the cranial structures were repetitions of the osseous quantities proper to the cervical vertebræ. It is said by some anatomists with Meckel, that Frank first recognised this analogy between the skull and the vertebræ (Sammlung Auserlesener Abhandlungen, Band XV. S. 267.). Burdin supposed the head to be a complicated vertebra (Cours d'Etudes Médicales, Paris, 1803, vol. i. p. 16.). Keilmeyer believed the same. Next Geoffroy St. Hilaire, Dumeril, and Goethe extended the theory, making such observations as are at present considered to be purely hypothetical, and little better than fanciful vagaries which almost overshadow the first truth. The similitude drawn by Goethe between the facial bones and the vertebræ, is scarcely less absurd than the likeness which Oken and Spix are supposed to have seen between the temporal styloid process and the sacrum, or between the hyoid apparatus and the pelvis. Hence, it is not to be wondered at why Cuvier mocked the cranial vertebral theory, when we find Spix seeking for a repetition of the regions of the trunk of the body in the head; and, because he would bend nature to his wild unstable fancy, whether she were willing or otherwise, so we have him representing the pelvis in the temporal bone; and likening the hind limbs to the lower maxilla; the auditory ossicles to the pubis; the maxillary condyle to the femur; the coronoid process to the tibia, &c. &c. See Cephalogenesis, seu Capitis ossei Structura. For Oken's views of this subject, see Isis, 1820, No. 6. p. 552.; Esquisse d'un Système d'Anatomie de Physiol. &c., Paris, 1821, p. 41.; also Ueber die Bedeutung der Schadelknochen, Jena, 1817.

point to which I direct the reader's attention, for it is upon this assertion that I found the present reading. If, for example, from foregoing remarks I have proved that the spinal vertebra is not a whole quantity, as it exists either in the cervical lumbar sacral or caudal regions, but that it is in reality a proportional metamorphosed from the sterno-costo-vertebral archetype, then it must follow that the figure which has been named cranial vertebra is also a proportional metamorphosed from the like archetype; for that which is true of the form we name spinal vertebra, must unquestionably be true of the cranial form, which we liken to a vertebra.

Now, in each of those spinal forms which hold serial order from cranium to the other extreme, there exists, as I have already shown, some proportional of the rib. In the thoracic spinal segment, the rib is plus, and meets its fellow of the opposite side at the sternal piece. This thoracic costo-vertebral form I have named archetype, and compared with it I have shown that all other spinal vertebræ vary from it, not because of the introduction of any new elemental part found in any of them, and not found in the archetype, but simply because they are, compared with this archetypal or plus quantity, the minus proportionals of such plus archetypes. However, it is still most true that the quantity which we recognise as the cervical lumbar or sacral vertebra, does contain within itself the rudiment of the rib, and therefore I repeat that this rib makes an integral part of all vertebræ — of all those, at least, which possess a certain quantitative character.

It must have already appeared evident to the reader that it was premature to have sought to establish an identity between cranial and spinal segments, without having first ascertained the quantitative nature of the thing which was named vertebra. For as it was evident that something was yet to be proved by the comparison of spinal vertebræ, so therefore it was not possible to prove all that might be known of cranial vertebræ, while prematurely referring one unknown quantity to another equally unknown — I mean the spinal vertebra to the cranial vertebra. Since it was by no means as yet demonstrated that the form which anatomists recognised as the spinal vertebra was a quantity of fixed and invariable character, how then could it be proved that the form to which it was likened in the cranium was of fixed and unvarying dimensions?

When anatomical science, lighted by the torch of Oken's genius, first pierced the mist and obscuring cloud of nomenclature, which described the cranial structures as distinct from the spinal forms, and when it expounded the facts and doctrine of that radical homology of caste which related both classes of structure together under the common name vertebræ, it did not in truth progress much nearer to the explanation of the law of form than when it first explained, despite of nomenclature, the analogy which existed between sacral bones and lumbar vertebræ. In the one case it only related hitherto unknown forms to vertebræ, without knowing the typical form of vertebræ themselves; in the other case it related the sacrum (sacer) to the lumbar vertebræ, and called both vertebræ, without having any idea of the vertebral archetype or whole quantity.

The facial apparatus is to the cranial forms just what the thoracic costæ are to the dorsal vertebræ, namely, the integral parts of whole sacral quantities.* As in thoracic series, it is required that we should take the dorsal vertebra, holding its natural connection with the thoracic rib, and describe both as the parts of whole thoracic quantities; so in cephalic series, we are reminded, from the natural connection which facial structures hold with cranial forms, to describe both orders of parts as constituting the whole cephalic quantities. It is upon this connection apparent between facial and cranial structures at one region of series, and between vertebral and costal structures at another region of the same serial order, that I am induced to draw a likeness or resemblance, as well between costal forms and maxillary forms, as other anatomists have recognised between cranial forms and spinal vertebræ. The identity which is already proved to exist between the latter must prove the identity of the former likewise. The homology of caste which *à priori* reasoning establishes between cranial and spinal forms, will lead us to interpret by *a posteriori* reasoning that an homology of caste must characterise the costal and the maxillary forms; for if we are already forced to acknowledge identity between cranial and spinal vertebræ, so must we, I contend, be induced to name the maxillæ of cranial vertebræ to be the homologues of the costæ of spinal vertebræ (even if special modification had rendered homology still more obscure than it is at present), and for this reason, viz. that costæ are the natural attendants upon vertebræ, wherever we find vertebræ, whether in the head or in the spinal serial axis.

As all spinal segments whatever contain some proportional of a rib, it must follow that the rib is to indicate the presence of the vertebral piece as much as the vertebral piece implies the presence of the rib; and if the cranial forms are proved to manifest a structural identity with spinal vertebræ, while we see that the latter are always attended with

* If the facial be to the cranial structures just what the thoracic costæ are to the dorsal vertebræ, then it will appear evident to the reader that, when Oken, or Spix, or Goethe, or Geoffroy likened the facial structures to vertebræ, they committed an error as evident as if they saw an analogy of form between the thoracic ribs and the vertebral pieces. Schultz (De Primordiis Systematis Ossium et de Evolutione Spinæ Dorsi in Animalibus) was the first to pronounce the gross error into which the transcendental anatomists had fallen in respect to likening the facial apparatus to the vertebral pieces. Bojanus, in like manner, prudently freed himself from this error. Professor Owen considers the facial apparatus to consist of the "inverted arches" of the cranial vertebræ.

the ribs, then the cranial vertebræ, as vertebræ, must have the ribs also. What other cephalic structures, therefore, are there in the head which may be said to stand as the ribs of cranial vertebræ, if these ribs be not the maxillary arches ? *

Now there happens in *fig.* 481., between the costiform maxilla ($d\,d^*$) and thoracic ribs

Fig. 481.

The human cranio-facial and cervico-hyoid apparatus,

Showing that the hyoid apparatus relates to the cervical vertebræ, and the facial apparatus to the cranial vertebræ, just as the thoracic or costo-sternal apparatus relates to the dorsal vertebræ.

($p\,p^*$), that hiatus or gap in costal series which is called the cervix, and it is this hiatus ($q\,q\,q$) which interrupts the idea of a continuous serial costal order ; at the same time

* In the "Homologies," the author names the maxillæ the "inverted arches" of the cranial vertebræ. These inverted arches answer to the hæmapophyses of the author's ideal typical vertebra, and not to the pleurapophysial elements (the ribs) of that ideal form. Now I confess, for my own part, that I do not see clearly why these maxillary arches are referred to the former rather than to the latter elements. There is evidently some mystery about this ideal typical vertebra figured in the "Homologies," which I cannot penetrate, and for this reason, viz. that I find the author's "ideal typical vertebra," while compared to the osseous segment taken from the bird's thorax, and which he terms the "natural typical vertebra," does not correspond quantitatively. In this ideal form I find the ribs (pleurapophyses) but as mere rudiments, whilst in the natural form I see that these ribs embrace thoracic space from the spine nearly to the sternum. Again, in the ideal form the hæmapophyses hang appended to the vertebral centrum ; whereas in the natural typical form they articulate with the distal ends of the thoracic ribs.

that vertebral series (G, H, I, K, L, M, N) is still uninterrupted as it passes from dorsal vertebræ (P), through cervical vertebræ, to cranial vertebræ (F, E, D, C, B, A). Thus we find that vertebral series persists continuously, while costal series is interrupted by the cervical hiatus happening between the maxilla above and the thoracic costæ below. This hiatus is caused by the degradation of costal quantity simply, for we still see that rudimentary ribs (g, h, i, k, l, m, n) are developed upon each of the cervical vertebræ. If the original plus ribs of the cervical vertebræ still persisted at the lines $q\,q\,q$, for them as the plus ribs ($p\,p^*$) do for the dorsal vertebræ, then we should have the maxilla holding serial continuous order with the thoracic ribs, in which case it could scarcely be doubted that the maxillæ were structural homologues of the costæ elsewhere. But in this occurrence of cervical hiatus, which results by the metamorphosis of that plus costal quantity which I consider to be originally proper to the cervical vertebræ, we have the facial apparatus now disconnected from the thoracic apparatus; and the only structural entity which at present relates the maxilla above to the costæ below is the hyoid apparatus (f^*, g^*, h^*, l^*, k^*). Hence this latter structure can come of no other source than cervical original costal quantity under metamorphosis.

The idea of the plus costal quantity, which we now know to be lost at the cervix, is equal to the idea of the same quantity present; and hence, when I say that they are the plus ribs which are lost to cervical vertebræ, it is as strong an idea as if I still viewed them persisting at the lines $q\,q\,q$. If these cervical plus ribs still persisted, they would leave no doubt that the maxillæ are of costal origin. Indeed the maxillæ, as they at present stand, prove a much stronger resemblance to ribs than cranial vertebræ do to spinal vertebræ; and if we see little reason to doubt the identity between the latter structures, there is, as it seems to me, even still less reason to doubt the homology or correspondence between the two former.

In *fig.* 481. I have indicated the number of those vertebral forms which constitute the human cranium, taking as my guide the invariable attendance of the costal structure upon the vertebral structure, as well in the head as in all other regions of the spinal axis. The first dorsal vertebra (P) is attended by the plus ribs ($p\,p^*$), stretching over thoracic space from the back to the sternum. All the cervical vertebræ (N, M, L, K, I, H, G) are likewise attended by the minus costæ (n, m, l, k, i, h, g). From these severally I have produced lines to the hyoid apparatus, and these lines, together with the hyoid pieces, indicate thoracic costo-sternal quantity, which metamorphosis has degraded down to the quantities at present forming the cervical region. The intervals between the cervical lines of the original costæ are marked ($q\,q$) as corresponding with the intercostal spaces.

The atlas (G) supports the occipital or first (reckoning from below) cranial vertebra. In the atlas vertebra * may be recognised (g) the vertebral end of its rib, which when produced through the line q joins g, the greater cornu of the hyoid bone, to which latter the body g^* is attached; this group of elementary parts represents the debris of the archetypal sterno-costo-vertebral quantity; the atlas stands in series with the other vertebræ, while the inferior half of the hyoid bone holds series with the sternum. The axis vertebra (H), in the same way, corresponds to the (h^*) thyroid cartilage. The third cervical vertebra (I) corresponds to the cricoid cartilage (i^*). The fourth vertebra (K), the fifth (L), the sixth (M), point to the rings of the trachea. The seventh vertebra (N) stands opposite to the clavicle (n), which I regard as the costa of that vertebra.

The *first* or occipital costo-vertebral quantity of the head consists of (F) the centrum and the pieces $1'''''$, 2, 3, which form the neural arch and spine. The rib and sternum or costo-sternal quantity of this vertebra is represented by the styloid process (f), which, when produced in a line to (f^*) the upper half of the hyoid body with its lesser cornu, completes this group of elemental parts.†

The *second* or petrosal costo-vertebral quantity of the head consists of (E) the centrum and the parts $1''''$, 2, answering to the neural arch and spine; the costo-sternal quantity of this vertebra is represented by the tympanic bone (e) coiled upon itself, and enclosing within its circle the auditory ossicles. The tympanic bone, together with the auditory ossicles, may be regarded as costo-sternal quantity, specially modified in subservience to the special sense of hearing.‡

The *third* or temporal costo-vertebral quantity of the head has no part corresponding to the body at D; but the neural arch and bicleft spine of this segment of the skull are represented by the parts $1'''$, 2. The costo-sternal quantity of this vertebra is represented by the lower maxilla (d) articulating like a rib with the glenoid cavity (d). §

The *fourth* or post sphenoid-costo-vertebral quantity consists of (C) the centrum and the parts $1'''$, 2, answering to the neural arch and spine. The costo-sternal quantity of this vertebra is represented by the zygoma (c, c) and upper maxilla (c^*).

* Professor Owen refers the clavicles to the atlas vertebra, and considers them as forming the hæmal inverted arch of this vertebra. See "Homologics," &c.

† The scapulary limbs are referred by Professor Owen to his occipital vertebra, of which he considers the scapulæ to be the ribs, and the rest of these members to represent what he terms the "diverging appendages."

‡ Professor Owen does not regard the petrous bone as a part of a cranial vertebra, but he calls it a "sense capsule," and refers it to the splanchno skeleton.

§ The styloid process is regarded by Professor Owen as the rib of his parietal vertebra.

The *fifth* or anterior sphenoid costo-vertebral quantity consists of (B) the centrum and the part $1''$, as the neural spine. The costo-sternal quantity of this vertebra is represented by (*b*) the palate bone.

The *sixth* or ethmoidal costo-vertebral quantity of the head consists of (A) the centrum, with the part $1'$ as the neural arch. The costo-sternal quantity is represented by the nasal bones (*a*).

Now, considering *fig.* 481. as a whole, I find it to be characterised in certain ways, which still further prove the nature of the fact, that the human head consists of six* costo-vertebral archetypes, as numbered above; and though I by no means would have it understood that I consider each of those cranial archetypes to be equal in quantity either to one another or to the first sterno-costo-vertebral quantity of the thorax, still I find that there are certain sutural marks in the human head and facial apparatus, which seem to define, with sufficient clearness, those natural groups of bones which form the archetypal quantities. The spaces called intervertebral, amongst the spinal vertebræ, viz. those spaces which occur between the neural arches of two adjacent vertebræ, such as G and H, are represented by all the transverse sutures of the cranium. Those sutural intervertebral intervals I have marked thus: Between the axis H and the atlas G, the intervertebral space is o'''''''; between the atlas G and the occipital form, the space is o''''''; between the latter and petrous form is the lambdoidal suture o''''', and so on. The intercostal spaces are marked *q*, *q*, &c.

When we seek to determine the nature of the sutures of the cranial structures by comparison with the serial vertebræ of spinal order, we should bear in mind the fact that one order of the cranial sutures must correspond to the intervertebral spaces of spinal vertebræ, while another order of cranial sutures must answer to those points where the elements constituting each vertebra join. Thus, whilst such sutures as the coronal (*fig.* 481. o',) and lambdoidal (o''''') answer to the intervertebral spaces (o'''''''), the sutural temporo-parietal point of union between $1''''$ and 2 answers to the point of junction between the elements 1, 2 of the atlas vertebra G, or of the axis H. The frontal suture is that line of union which the symmetrical laminæ of one vertebra of the spine would, when meeting each other at the median line of neural space, represent. The sagittal suture is a bicleavage of the spinous process (viz. the symmetrical parietal bones) of that vertebra of the head to which they belong.

As the nerves passing from the spinal cord bear a somewhat fixed relation to spinal vertebræ, so might we expect that the nerves of the encephalon should bear the like relationship to the cranial vertebral quantities. A spinal nerve passes between two adjacent vertebræ, and thus to six spinal vertebræ there correspond five nerves. I have enumerated six cranial vertebræ, each one with the costal quantity, and hence the nerves passing between these six should number five, like those of the spine. These cranial nerves I consider to form five natural groups, as follow:—

The *first* or olfactory nerve, being one of special sense, is distributed upon the ethmoid vertebra (*fig.* 481. A). The *second* is a group of motor and sensory branches, consisting of the optic, the third, and the fourth nerves, which pass through the optic and lacerate foramina or cleft, which occurs between the ethmoid and anterior sphenoid vertebræ. The *third* group of nerves is motor and sensory, consisting of branches of the fifth, which pass through the foramen ovale (*fig.* 482. *e*). The *fourth* group of nerves is motor and sensory, consisting of the portio mollis and portio dura; one of these nerves is distributed to the organ of hearing, and the other makes exit at the stylo-mastoid foramen (*fig.* 482. *r r*), being destined for the side of the face. The *fifth* group is also motor and sensory, and consists of the eighth and ninth nerves passing out through the foramina (*l*, *t*), viz. the anterior condyloid and foramen lacerum posterius.

The groups of foramina, which I consider as answering to the intervertebral foramina of the spinal series, are indicated in *fig.* 482., each group being surrounded by a dotted line, as at the point *e*, the place *s*, *m*, *r*, and the place *l*, *t*. The other two intervertebral foramina are not seen in this view of the cranial base. It is a singular fact that the external meatus occurs like a true intervertebral foramen between the petrosal and temporal vertebræ, which in the early fœtal condition are naturally separated. When I view the serial order of the intervertebral foramina of the cervical spine, I find that the external meatus exactly coincides with the series.

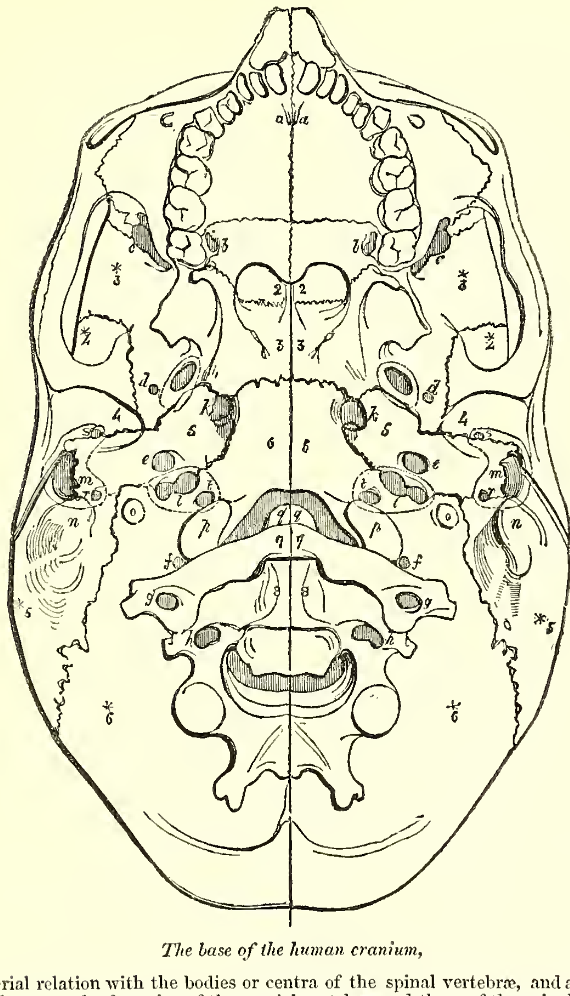
There are many facts of interest which recur to me regarding *fig.* 482. as a form comparable to vertebræ; but since to record these in full would exceed the space allotted to this article, I must forego the task, and only remark in brief, that all the other foramina of the cranial base give passage to arterial and venous vessels like the vertebral foramina (*g g*) of the atlas and (*h h*) of the axis.

The cranial base (*fig.* 482.) gives evidence of a certain fact of special modification of so large an interest, that I cannot but advert to it: the fact is this—the body of the axis (8, 8) passes through the body of the atlas (7, 7), and carries part of this latter (*q*, *q*) before it as its odontoid process. The body of the occipital vertebra (6, 6), passing forward to the body of the post sphenoid vertebra (3, 3), sunders the body of the petrosal vertebra (5, 5), while the body of the parietal vertebra

* Professor Owen enumerates four cranial vertebræ, viz. the occipital, parietal, frontal, and nasal. He regards the ethmoid to be a sense capsule, like the petrosal bone, neither of which he considers to be parts of vertebræ. Oken held the same opinion. Spix, Bojanus, and Geoffroy left these bones undetermined as to their homological signification.

is altogether obliterated. By this circumstance of the body of the sixth or occipital cranial vertebra joining the body of the third or post sphenoid vertebra, the cranial basis is contracted in its longitudinal axis, while the cranial vault (*fig.* 481.) fashioned of the

Fig. 482.



The base of the human cranium,

Showing its serial relation with the bodies or centra of the spinal vertebræ, and also the serial homology between the foramina of the cranial vertebræ and those of the spinal vertebræ.

expanded neural arches, affords ample space wherein to locate the crescent organ of the intellect.

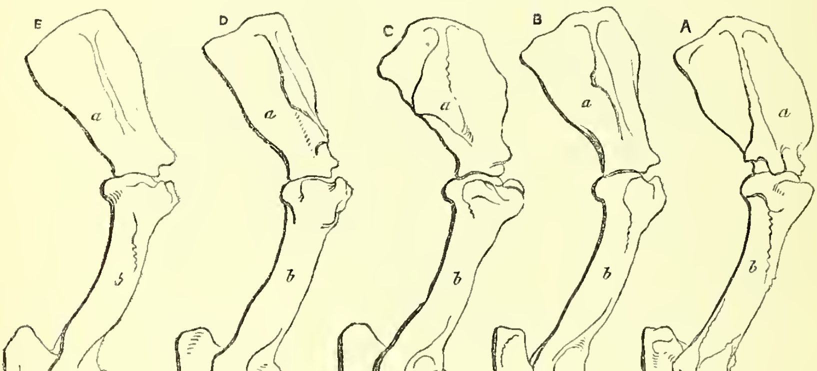
PROP. XL. *The scapulary or fore-limbs of all the vertebrated animals are homologous to one another. The variety among these organs occurs by a metamorphosis or omission of elementary quantity.*—The right scapulary organ is perfectly identical with the left in the same animal body. Both the fore-limbs of the human body are identical; those of other mammals are identical; those of a bird are identical; those of a reptile are identical; and those of a fish are also identical. Osseous quantity is equal for both fore-limbs of the same animal. But the fore-limbs of all animals are not quantitatively equal, far from it. The fore-limbs of a mammal differ by quantity from the fore-limbs of a bird, those of a bird from those of a reptile, and those of a reptile from those of a fish. The mammal fore-limbs manifest a quantitative difference amongst all species of that class; the avian fore-limbs the same; the reptilian fore-limbs the same; the piscean fore-limbs the same also. The anatomist who would undertake the task of recording the quantitative difference manifested amongst all the fore-limbs of the vertebrated classes, would require a chart as free as space and a leisure as unconfined as time. As quantitative difference is of such infinite account, I shall not therefore record it by the numerical method; but my task shall rather be to develop that idea in generalisation, which will interpret the infinity of variety as

being the product of a law of metamorphosis, exercising itself upon the whole quantity or unity.

Comparison teaches me the fact that not only are the fore-limbs of the animal classes varied amongst themselves as to osseous quantity, but I find that even the individuals of any one species have not the fore-limbs developed of invariably fixed and equal quantity; for there is no one species free from the possibility of that occurrence which we term "anomaly." The human hand is seen to develop (by no means unfrequently) a plus number of digital appendages. I have seen the like anomalies upon the fore-hands of the Quadrumana. The Ruminantia now and then develop in the fore-foot solipedal character. The solipedes are known to produce the fore-limbs in cloven stamp sometimes. The individuals of every species, I doubt not, would, if we studied them with sufficient care and in large masses, prove themselves to be subject to the occurrence of a plus or minus quantitative variety to that character which is general or normal with them. It is because I find that these anomalies to species are facts not more marvellous in themselves than are the facts which vary species to species, that I will here embrace them in the general interpretation of a plus unity undergoing metamorphosis for the creation of variety. The variety between species can be nothing more than the variety which the anomaly proves to the species of normal character.

There is no member of the animal fabric which more interestingly illustrates the fact that nature adheres to a unity of type than does the osseous fore-limb. Whatever be the variety which fore-limbs manifest, when comparatively contemplated, still we find that the bond of unity embraces and girds within its circlet the whole subject of the variety. A proof of this fact may be seen

Fig. 483.



A, the fore limb of the lion; B, that of the wild boar; C, that of the rhinoceros; D, that of the bull; E, that of the horse; showing a serial degradation from plus to minus quantity.

even in the use of that nomenclature, by which we designate all varieties of the scapulary organ; for, were it not that all such members proved a greater or lesser similitude the one to the other, we should not and could not afford to generalise them under the common appellation of scapulary organ.

The fore-limbs of all osseous skeletal fabrics

(*fig.* 483.) are alike as to those segments which constitute them one and all. Those segments are the scapula (*a, a*), the humerus (*b, b*), the fore-arm bones (*c, d*), the carpal ossicles (*e, f*), and the metacarpo-phalangeal series (1, 2, 3, 4, 5). Every species of the fore member produces these segments invariably; I say invariably, for I am not now referring to their pathological state.

When I compare all fore-limbs by the scapula (*a*) or proximal segment, I find that this bone is invariably present, though very much modified in several animals. As all scapulary organs of mammals, birds, reptiles (and I would add the osseous fishes, but for certain facts which require previous explanation,) produce the bone named scapula, they may be hence termed uniform as to this particular. The invariable occurrence of the humerus (*b*) renders them likewise uniform as to this segment. But though the fore-arm carpus and metacarpo-phalangeal segments are, as segments, invariably present likewise, still all fore-limbs are not equal or uniform as to the quantity contained in each of these segments. Considering the fore-limbs under general notice, I see that they are uniform by the proximal ends (*a, b*) of the organs, and variously by the distal or terminal appendages. But it is most true, nevertheless, that this variety is only quantitative, or simply a plus and minus variation, for A produces five digits, B four, C three, D two, and E only one.

Of the two bones (*c, d*) constituting the fore-arm, that one which is most constantly developed in entire proportions is the radius (*c*). The ulna (*d*) is very often reduced to almost unrecognisable dimensions (*d* of E); and that part of the ulna which is most generally metamorphosed or annihilated is its distal or carpal extremity. The olecranon process and a part of the shaft of the ulna is always present.

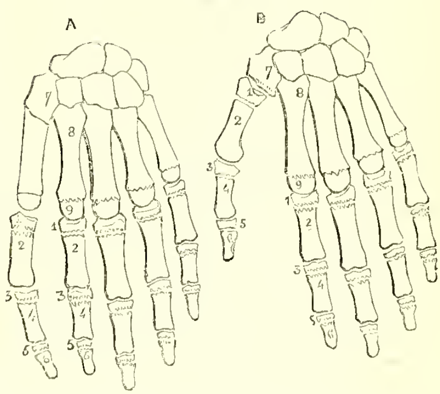
The carpal ossicles (*e, f*), which in all fore-limbs manifest a greater relationship to the radius (*c*) than to the ulna (*d*), are as constant as the radius itself. The metamorphosis of the ulna (*d* of E) does not appear to affect the carpal ossicles (*e, f*).

The metacarpal bones (*fig.* 483.) are numerically various in these scapulary organs. Though it be true that we find them in all fore-limbs, still we do not find them produced in equal numbers. The metacarpal bones are not constant to the number of five; but though we find them varying in a plurality of animals from the number of 5 in A to that of 1 in E, still we should not overlook the fact, that in certain fore-limbs, as D and E, where, to all appearance at first sight, a single metacarpal bone is developed, a closer inspection will prove that others may be present, though in rudimental form (5 of E).

The phalangeal ossicles (2, 4, 6, of B, *fig.* 484.) which constitute a finger are usually three in number; but there are exceptions to this rule. The fingers themselves are generally found to correspond in number with the metacarpal bones. When there are five metacarpal bones, the fingers are five in number also. When animals have only four, or three, or two, or one metacarpal bone (*fig.* 483.), the fingers number accordingly. There may be more metacarpal bones than there are fingers, but as many of the fingers as are present, whatever be their number, have each invariably a corresponding metacarpal bone. The rudimental metacarpal bones have, generally speaking, rudimental phalanges.

The thumb varies as to the number of its phalanges, and becomes a finger or a thumb according to this occurrence. The metacarpal bone of the thumb is very often present when the phalangeal thumb ossicles are absent; and sometimes I find that some species of animals have only one phalanx for a thumb; sometimes two, sometimes three. The digit which is a thumb in one animal (*fig.* 484. B), by reason of the fact that it stands apart from the other digits, is now and then laid side by

Fig. 484.



side (A) with the other digits, and becomes a finger accordingly. I have reason to believe that the bone (1, 2, next to 7 of B) which we term metacarpal bone of the thumb in one animal is the true homologue of the first phalanx of the finger appended to 8 of A, and for this reason, viz. that the metacarpal bone of the human thumb (1, 2 appended to 7 of B), is constituted of two ossicles, which have become consolidated. If we class the hindmost ossicle (1 of the bone, 1, 2 appended to 7 of B) with the other metacarpal bones, then the foremost ossicle (2) will represent the first phalanx (2) of the other fingers, and this will give (as in A) three phalanges to the thumb, as to the other fingers. It is worthy of notice, that the so-called metacarpal bone of the thumb (1, 2 of B) corresponds as to nucleary deposit with the first phalanx (1, 2) of the finger.

The foregoing mentioned facts respecting the scapulary organs will prove that they are "unity in variety," the unity being a plus quantity (as A, *fig.* 483. with five digits); whereas the variety is simply a minus quantity, so rendered by the degradation or metamorphosis of the quantity of five digits, which

are proper to the plus original. This interpretation will, I believe, stand the test of rigorous reasoning, and will teach the anatomist this, or nothing truthfully besides this, viz. that if the presential characters of the fore-limbs manifest such a diversified condition as precludes him from naming them quantitatively equal and uniform things, still the diversity, such as we find it, can have occurred by no other process or law, save that of degradation or the metamorphosis of elemental parts. A certain part is wanting to one organ compared with another organ; and if it be by reason of the want of this part in one organ, which part is present in another, that I am unable to name both these organs uniform, it is no less true that this very want of the part constitutes the species.

The fore-limbs of the man, the horse, the ruminant, the carnivore, the rodent, the marsupial animal, the bird, the reptile, are not quantitatively uniform things, and this is the only reason why they are various things. If it be this quantitative difference which induces us to classify them separately, it is only this same mode of difference which stands in our way preventing us from naming them absolutely alike. The one organ has one part which the other organ has not, and therefore both organs are various or special; but it is still most true, that it is the want of the known part rather than the superaddition of an unknown part which constitutes both organs thus special.

The special thing compared with the ideal unity is simply the minus quantity compared with the plus quantity. All comparative method proves this. When I compare the fore-limb of the ass with the arm of the man, and endeavour to ascertain the law which has rendered the first as a form special to the last, I find that my analysing instrument must be not the scalpel but the calculation. For while I see that in the soliped member are arranged certain parts taking order in the self-same manner as the like parts in the human arm; and while I further discover that the latter organ developes certain parts, which parts are not developed for the former, and that hence only arises the difference or species; I must therefore conclude that the species depends upon the absence of something, which thing, being absent, I cannot dissect by any other instrument than the understanding; and the thing, though absent, may be still visible to the mental although invisible to the physical eye.

For the knowledge of the thing absent, viz. some of the digits of E, *fig.* 483., is, I contend, equal to the knowledge derivable from the actual presence of the very same quantity, viz. those digits in A; and, therefore, so long as I know the quantity which is absent from one ens to be the same as the quantity which is present to another ens, this must furnish me with the idea of equality, or the uniformity, as saliently as if the quantity were present for both enses. When, for example, I compare the soliped or the cloven foot with the human hand, I find that the lesser ens is contained in the greater ens, and that the other parts, which are wanting to the lesser, are still manifest in the greater; therefore I conclude, that as the greater, viz. the human hand, can undergo a metamorphosis or subtraction of parts, so as to reduce it to the proportions of the cloven or the soliped organ successively, so has the original or plus quantity, which may be regarded as equal to the human hand, undergone a metamorphosis of parts in such degree as now yields for our contemplation the special or minus quantities, which we name cloven or soliped foot.

PROP. XLI. *The scapulary and pelvic members are homologous.* — In a former place I have given reasons why we should consider the clavicles, the pubic, and ischiadic bones as the homologues of ribs; and therefore I shall not need their presence in this place while holding comparison between the fore and hind members.*

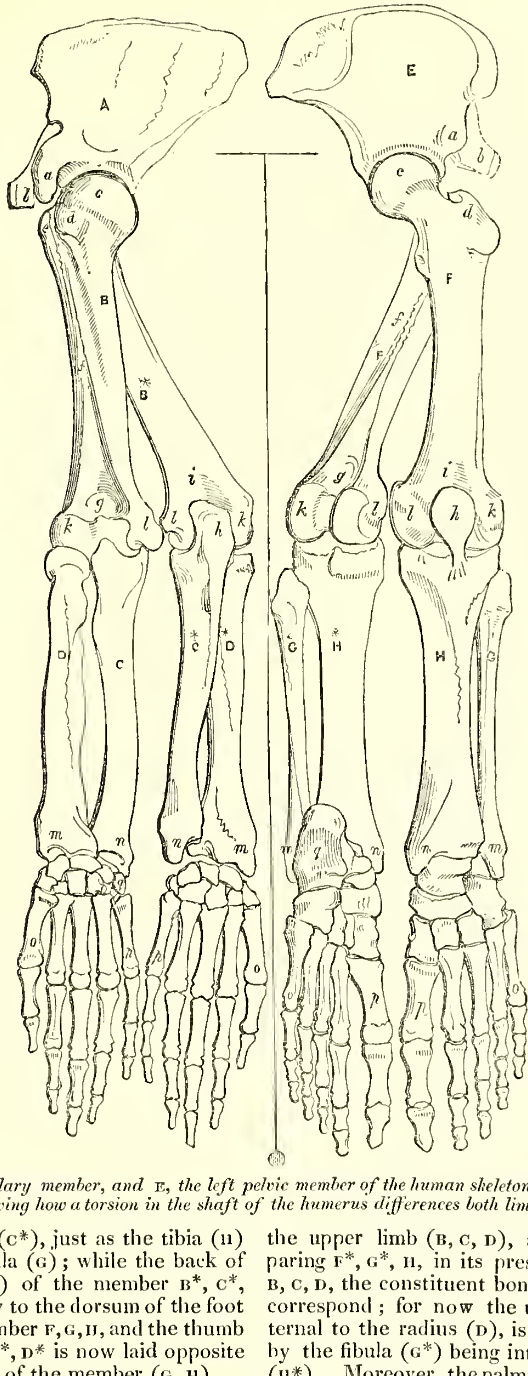
The fore-limb (*fig.* 485. A.) separated from the clavicle, consists, like the hind limb (E), separated from the pubis and ischium, of a fixed and invariable number of segments; and the parts which constitute these segments in both are absolutely corresponding. The scapula (A) corresponds to the ilium (E); the humerus (B) to the femur (F); the radius (D) to the tibia (H); the ulna (C) to the fibula (G). The hand is manifestly the counterpart of the foot. The carpus represents the tarsus; the metacarpus corresponds to the metatarsus; the phalanges of the hand are represented in the phalanges of the foot. The pisiform bone (*q*) of the carpus is similar to the os calcis (*q*) of the tarsus; the great toe represents the thumb; the little toe simulates the little finger. The common structural identity between both organs is plainly manifest at all points save one; and this, though often attempted to be explained, has not as yet yielded up its mystery. How happens it that the patella (*h*) and fore aspect of the hind limb (E), corresponds to the olecranon (*h*) and back of the fore-limb (A)? I believe that the complete solution of this problem may be had from the following remarks made in reference to *fig.* 485.

On comparing the right scapulary organ (A, B, C, D) with the left pelvic member (E, F, G, H), I find that the fore aspect of the former does not correspond to the fore aspect of the latter; but when I compare the back of the arm A, B*, C*, D* with the front of the lower member (E, F, G, H), their correspond-

* Vicq d'Azyr regarded the coracoid and acromion processes of the scapula as representing the pubic and ischiadic bones, while Cruveilhier states it as his opinion that the spine and acromion process of the scapula has no part analogous to them in the ilium. Professor Owen considers the clavicle as the homologue of the os pubis, agreeing in this view with Cruveilhier. But, according to Professor Owen's views, it is not with the rib that either the clavicle os pubis or ischium manifests an homology; on the contrary, he regards the iliac bone and the scapula as the true representatives of the ribs — his pleurapophysial elements.

ence is at once manifested; for then we have the olecranon process (h) of the ulna C* in the exact position of the patella (h) of the lower member (E). Moreover, in this new position of the scapulary organ (B*, C*, D*), we find that the position of the bones generally correspond with those of the pelvic organ (E, F, G, H); for the radius (D*) is now

Fig. 485.



A, *The right scapulary member, and* E, *the left pelvic member of the human skeleton, compared; and showing how a torsion in the shaft of the humerus differences both limbs.*

internal to the ulna (C*), just as the tibia (H) is internal to the fibula (G); while the back of the hand (n, m, p, o) of the member B*, C*, D*, corresponds now to the dorsum of the foot (n, m, p, o) of the member F, G, H, and the thumb (o) of the member C*, D* is now laid opposite to the great toe (p) of the member (G, H).

Now, I also find that the back of the lower member (F*, G*, H*) represents the front of the upper limb (B, C, D), and that on comparing F*, G*, H, in its present position, with B, C, D, the constituent bones of both organs correspond; for now the ulna (C), being internal to the radius (D), is exactly simulated, by the fibula (G*) being internal to the tibia (H*). Moreover, the palm of the hand (m, n, o, p) of the limb (B, C, D) is now turned forwards, like the sole of the foot (m, n, o, p of

G*, H*), while the pisiform bone (*q*) of the hand corresponds in position to the os calcis (*q*) of the foot.

While it appears, therefore, an undeniable truth that that aspect of the fore-limb (B, C, D), which we commonly call the front, is in reality structurally identical with the back of the lower member (F*, G*, H*), whereas the front of the latter organ (F, G, H) is the structural homologue of the back of the upper limb (B*, C*, D*), let us examine closely into the cause of this singular difference between both organs. Anatomists have long since remarked upon the singular twisted form of the humerus. Cruveilhier speaks of the "groove of torsion directed obliquely downwards and forwards" on the humerus. This fact of torsion in the shaft of the humerus I consider as fully explaining the above mentioned peculiarities which distinguish the upper from the lower member. In primitive construction both members are identical; but this secondary modification, viz. the torsion of the humerus, is that circumstance which distinguishes them one from the other.

While, in idea, I untwist the humerus by bringing its back to the front, I at the same time unravel the gordian knot of that problem which has so long existed as a mystery for the homologist.

The back of the humerus (B*) presents a smooth and rounded form, like the front of the femur (F). If, in idea, I twist the femur (F) in its long axis, so as to bring its back to the front, then F* makes its linea aspera (*f*) perform a spiral curve forward, just as the spiral rough line (*f*) on the shaft of the humerus (B) manifests its own contorted character; and at the same time I bring the points (*g*, *k*, *l*), usually on the back of the lower end of the femur, forward, like the corresponding points (*g*, *k*, *l*) of the humerus (B). If, again, in idea, I untwist the humerus (B) in its long axis, so as to bring its back to the front, then B* uncoils its rough spinal line, and gives this line its primitive vertical direction, similar to what the linea aspera of the femur normally presents, at the same time that the points (*l*, *h*, *i*, *k*) usually at the back of the humerus (B*) are brought forwards like the points (*l*, *h*, *i*, *k*) of the femur (F).

In *fig.* 485. I have drawn both limbs, each in its front and back aspect, on either side of the common median line. When the reader will compare B, C, D with F, G, H, in reference to this line, he will find that though the ulna (C) approaches this median line like the tibia (H), yet that this position does not render both these bones structurally homologous; for, from the foregoing remarks in reference to the twisted condition of the limb (B, C, D), he must have learned that it is owing to this fact of torsion that the bone (C) (ulna) holds, in reference to the median line, the position of (H) the tibia, with which latter the ulna is not homologous. When we, in idea, untwist B, and bring it into the position of B*, then the radius (D*) comes into sidelong position with the median line, like the tibia (H); and now both these bones manifest their homologous character, as well in position as in general form. The hand and the foot are, also, by these movements made to correspond. Is it not a fact of singular interest, so far as it explains the law of nature in exercising these special modifications on the structurally identical fore and hind limbs, that when, in reference to the common median line, we untwist B, D, C to the position B*, D*, C*, we then render this latter of the same aspect, compared with the ideal twisted condition of F*, G*, H*, as the figure F, G, H commonly manifests compared with B, D, C?

While we bear in mind the foregoing explanation of the presential characters of the upper and lower extremities, we are enabled fully to recognise the homological relations of these two members, as well when viewing their several constituent parts as when considering them as whole or entire organs.

The coracoid process *a* of the scapula A answers to the anterior inferior spinous process *a* of the iliac bone E; the acromion process *b* of A to the obliterated process *b* of E; the head of the humerus *c* of B, and both its tuberosities *e d*, to the head *c* and trochanters *c d* of the femur F; the rough spiral line *f* of B to the linea aspera *f* of F; the outer condyle *k* of B to the inner condyle *l* of F; for it is owing to the twist of the humerus B that the condyle *k* lies outermost; the olecranon process *h* of B* to the patella *h* of F, the twist of the humerus explaining why the former part is at the back and the latter in front; the radius D on the outer aspect of the foramen to H, the tibia on the inner side of the leg, the twist in the arm-bone explaining this difference as to their position, and also why the ulna (C) lies at the inner side of the arm, while its homologue (G) the fibula appears at the outer side of the leg. I shall here leave the reader to pursue the thread of this subject as far as he feels inclined; for the first and radical difficulty being removed allows the subject to be easily followed through its secondary stages.*

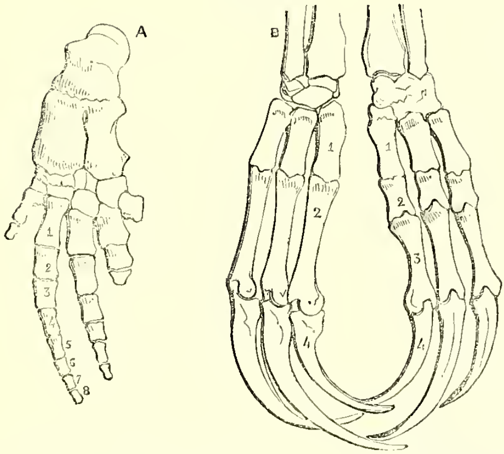
The fore-limbs of all species of animals are similar to one another in all respects save that of quantity, and this quantitative difference is manifested chiefly upon the distal extremities. The obliteration of one or more parts of the distal organ renders it in the varying conditions of those forms to which we give the names of hands, paws, wings, palms, talons, hoofs, &c; the same law of degradation is exercising on the distal extreme of the

* Vicq d'Azyr believed that the ulna represented the tibia, and the radius the fibula. M. de Blainville, on the contrary, regarded the tibia and the radius as homologous. Cruveilhier considered that neither of the bones of the fore-arm resembled, by itself, one of the bones of the leg, and therefore inclines to the belief that it is the upper end of the tibia which represents the upper half of the ulna, while the lower half of the tibia represents the lower half of the radius; moreover, that the fibula is represented by the upper half of the radius and the lower half of the ulna. See "Anatomie Descriptive," t. i. p. 315.

hind limb, and according to the quantitative variety of these organs we characterise them by the like names. The hand and the foot are radically the same organs, not only in the same body but in all bodies; and the law which differences these to an infinitude of special character is one of a phaseal quantitative degradation, and just as from the integer 9 may be proportioned the quantities 8, 7, 6, 5, 4, 3, 2, 1.

The distal segments of the scapulary and pelvic members are differenced by the operation of two laws, viz. that which subtracts quantity by its annihilation, and that which fuses plural elements into single parts. In *fig.* 486, B. the hands of the sloth present, numerically, various different stages of development. In the immature being, the parts 1, 2, 3, 4, correspond to the metacarpo-phalangeal series of the human fingers; whereas, in the adult animal, fitness requires that the elements 2, 3 should fuse into the bone 2, and thus duality becomes unity. On the contrary, in *fig.* A. we find the metacarpo-phalangeal series numbering as many as eight distinct elements holding permanently separate; and I may remark, as a curious fact, that this series of eight elemental parts corresponds

Fig. 486.



A, the fore limb of the whale; B, the paws of the sloth — immature and adult.

exactly to the number of those nuclei from which the metacarpo-phalangeal series of the fore-finger of B *fig.* 484. is formed.

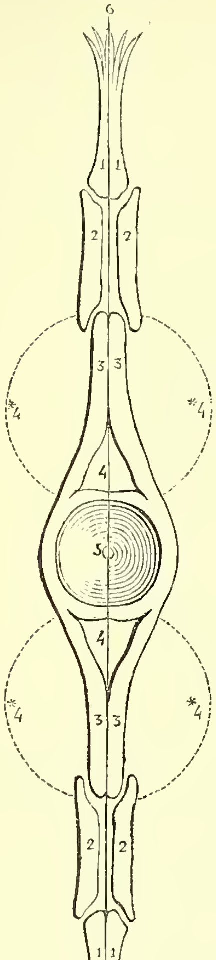
PROP. XLII. *The sterno-costo-vertebral quantity is a proportional of the dorso-ventral quantity.*—Every lesser form which manifests an identity with part of a greater form proves this, and nothing completely truthful but this, viz. that the lesser viewed in comparison with the greater, owes its present condition solely to the fact of its having been metamorphosed from such another quantity as the greater form. In the spinal axis of most fishes Nature develops a series of forms like *fig.* 487., which I call dorso-ventral, the dorsal half (1, 2, 3, 4) being quantitatively equal to the ventral half (1, 2, 3, 4); and the distal extreme (1, 1) of either half being terminated by fin processes, the palms (6, 6). In the spinal axis of terrestrial animals Nature presents a series of proportionally diverse forms, such as sterno-costo vertebral quantities, &c.; the dorsal sides of which are not quantitatively equal to the ventral sides, and these latter sides being still further struck proportionally diverse to each other. The difference between the spinal series of the terrestrial animal and that of the aquatic animal being a quantitative difference simply, forasmuch as the former are identical with some elementary parts of the latter, I here affirm that the lesser spinal quantity of the terrestrial animal is a proportional struck by metamorphosis from the greater spinal quantity of the aquatic animal. Let the comparative anatomist follow me in my remarks upon the skeletal axis of the fishes, and he will find that my explanation of the natural law of formation shall not outstep the demonstration which Nature herself offers as self-evidently truthful.

I point to a segment (*fig.* 487.) of the fish's spinal axis in that region of the series occurring immediately posterior to the thorax. This segment consists of a combination of elemental pieces (4, 3, 2, 1), arranged in symmetrical superposition upon the dorsal and ventral aspects of the part which we name the vertebral body, or centrum 5. An absolute identity prevails between the dorsal elements and the ventral elements. Those of the dorsum terminate in the dorsal fin (1, 6), while those of the venter terminate in the ventral fin (1, 6); such segment of the fishes' spinal series is evidently a whole complete archetypal quantity, forasmuch as it proves to be symmetrical whichever way I cleave it, whether horizontally or perpendicularly, provided the line of cleavage passes through the vertebral centrum (5). If I cleave this archetypal figure in the same modes as Nature herself does, I produce forms identical with Nature's forms, and create of it species like the species of Nature.

Nature cleaves the ventral half (4, 3, 2, 1) of

this dorso-ventral form (*fig.* 487.), and the result is *fig.* 488., having a pair of symmetri-

Fig. 487.

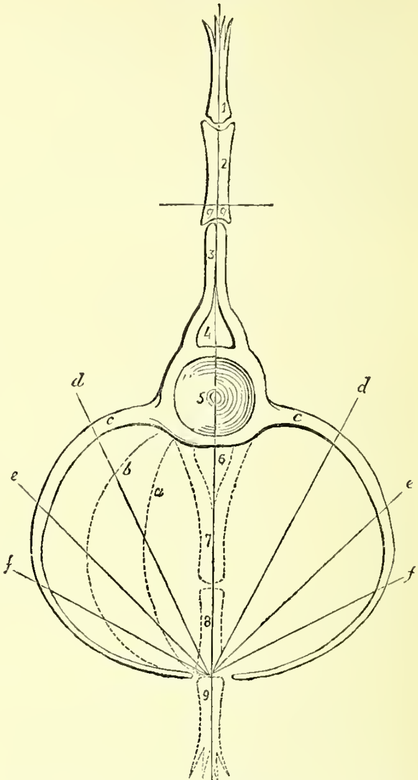


The dorso-ventral archetypal quantity, taken from the spinal series of the osseous fish.

cal ribs (*c c*) terminated by symmetrical palms or fins (9). The ventral space (*c*, *c*, *fig.* 488.) is now an apartment enclosed by ribs, in which are located the blood-circulating organs, together with the viscera of self-nutrition and reproduction. The dorsal space (4) encloses the nervous axis.

In *fig.* 487. the superior or neural arch (3, 3) encloses the neural space (4), and is surmounted by the interspinous bones (2, 2), to which is appended the symmetrical dorsal palm (1, 1). The hæmal or inferior arch (3, 3) encloses the hæmal or visceral space (4), and this arch, like the one above, has

Fig. 488.



The dorso-ventral archetype,

Showing how the ventral azygos ray is converted into the opposite pair of ribs by a vertical bicleavage through the median line.

attached to it ventrad the interspinous ossicles (2, 2), to which is appended, in like manner, the symmetrical ventral palm (1, 1). All these elements of the dorso-ventral archetypal quantity (*fig.* 487.) are bicleavable by the common median line (6, 6) passing perpendicularly through the centrum 5. If the ventral laminæ (3, 3) be sundered apart from each other to a width equal to the circle 4*, 4*, then these laminæ will enclose ventral space like the symmetrical costæ. The dorsal laminæ (3, 3) are quantitatively equal to the ventral laminæ ; and it is possible for the former to be sundered apart so as to form a neural circular space equal to 4* 4* ; but it never happens that this circular space has occasion to be formed around the neural axis, for already the neural arch (4) is sufficiently capacious for its contents, and therefore the space (4) formed between the dorsal laminæ (3, 3) is of dimensions, in all spinal axes, equal to the spinal cord.

But the symmetrical sides of the ventral ray of the archetype (*fig.* 487.) do actually widen apart from each other to a degree

according with the increasing bulk of the viscera of the thorax and abdomen; and in order to allow space sufficient for the reception of these organs, the ventral ray (3, 2, 1) suffers a cleavage through its whole length, as seen in *fig.* 488., where the original ventral ray (7, 8, 9) has widened into the costal circle *c*, *c*.

Now *fig.* 487., in its original azygos condition, or in its bicleft symmetrical form in *fig.* 488., may be so metamorphosed and proportioned as to produce every known form of vertebra in the spinal axes of the four classes of animals. The quantity of *fig.* 487., taken as a whole or archetype, represents the largest segment of all spinal axes, that, for example, which we find standing in the spinal axes of the Pleuronectidæ. The obliteration of several parts of the quantity (*fig.* 487.) will successively represent in the remainders many forms of vertebræ; for if the dorsal palm (1, 1) be subtracted from it, it will represent any of the palmless dorsal rays of the osseous fish; and if the dorsal palm (1, 1), with the interspinous ossicles (2, 2), be subtracted, then the dorsal laminæ (3, 3), which enclose the neural space (4), will represent any dorsal ray of the spinal axis of the terrestrial animal. When the dorsal and ventral palms (1, 1), together with the dorsal and ventral interspinous ossicles, are subtracted from the archetype (*fig.* 487.), then the quantity composed of (5) the centrum and of (3, 3) the neural and hæmal arches equals that vertebra which we find in the tail of cetaceans, viz. that vertebra which possesses the chevron bones. The chevron bones are fashioned of the inferior or hæmal laminæ (3, 3), and when the neural or the hæmal arch produces the neural or the hæmal spinous process, this process is a part of the interspinous ossicles left remaining, as at *g*, *g* (*fig.* 488.)

When the ventral ray (3, 2, 1) of the archetype (*fig.* 487.) widens to the costal arch *c*, *c* in *fig.* 488., this arch is left standing at the thorax of some animals, and even at the venter of others. As *fig.* 488. stands in its present quantitative character, it may be found in the abdomen of fishes still having the parts 1 and 2 attached and persisting, or obliterated and lost to the original quantity, as the case may require. At the dorsal aspect of the spinal axes of all terrestrial animals it may be understood that the parts 1 and 2 of *fig.* 488. are lost or subtracted.

It is the ventral ray, consisting of the parts 7, 8, 9 (*fig.* 488), which suffers median cleavage and widens into the costal arches (*c*, *c*). As a certain proof of this fact, I may remark, that where the full ventral ray persists as at 7, 8, 9, there we never find the full costal arches (*c*, *c*) existing; and where these latter are existing, there we never find the ventral ray. As the one becomes converted into the other, it is hence impossible for the same ens to exhibit both conditions of form at one and the same time.

When the ventral ray 7, 8, 9 (*fig.* 488.) has widened into the costal arches, these arches may and do suffer a metamorphosis of quantity to the same degree as when in their original azygos condition. Thus the ribs (*c*, *c*) become symmetrically proportioned or obliterated successively at the points *f*, *e*, *d*, by imaginary lines radiating from the sternal centre at 9. When these costal arches (*c*, *c*) meet at the central point 9, then we name the ribs *sternal;* when they fall short of this point 9, either at the point *f* or *e*, we name these ribs *asternal;* when they become obliterated as far back as the point *d*, then we name them, as in the lumbar spine, the transverse processes.

As every law in nature is phaseal and graduated, so is this the distinguishing character of the law of formation. The ventral ray (7, 8, 9), after undergoing a cleavage into symmetrical halves, will present, in various classes and species of animals, a phaseal gradation in the process of widening, and assume the form of the arc *a*, *b*, and *c*, successively, according to necessity.

In the caudex of the saurian or cetacean, we find vertebræ producing at the same time the neural arch and spine, the hæmal arch and spine, together with the costal process (*c*, *c*), jutting laterally from the centrum (5) as far as the point *d;* when this is the case, then the hæmal arch and spine is fashioned of that quantity of the costæ which intervenes between *d* and *f*, and which, being severed from *c* at the point *d*, is bent inwards towards the median line 6, 7, thus assuming a second time its azygos position. In some aquatic mammalia (the porpoise, dolphin, &c.) there remains at the dorsal aspect some trace of the dorsal form (1, 2, 3, of *fig.* 488.). The cetacean dorsal fin is thus explained.

PROP. XLIII. *The scapulary and pelvic pairs of limbs are proportional quantities metamorphosed from the dorso-ventral archetypes.*— The scapula disconnected from the clavicle is the quantitative counterpart of the iliac bone separated from the os pubis and ischium. Having in a former place remarked upon the structural homology which relates clavicles, pubic bones, and ischiadic bones to ribs; and having also pointed out the homological relations between the scapulæ and the iliac bones, we shall in this place first consider the structural homology between these latter osseous quantities and the vertebræ, and next the homological relations between the fore and hind limbs, the ribs, and the dorso-ventral rays.

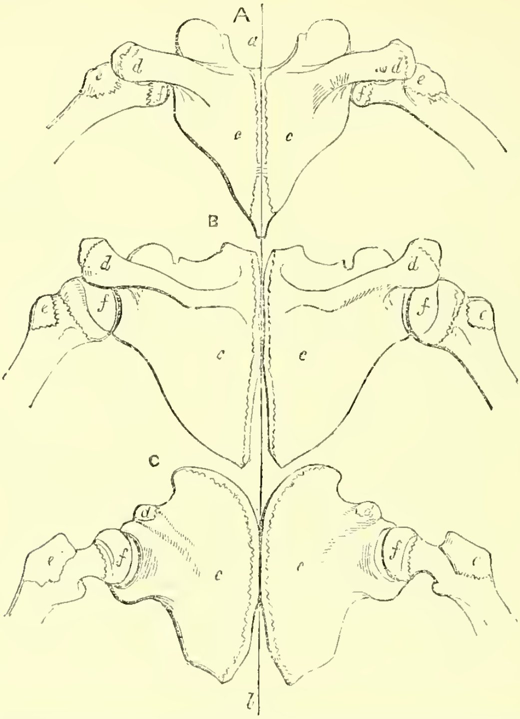
The dorsal vertebra, viewed from behind, is represented in A (*fig.* 489.). B represents the dorsal aspect of the two scapulæ conjoined, and C represents the two iliac bones placed base to base. Is there a structural identity apparent between these three figures? and in what points of character do they correspond? To this question I answer in almost all points; for not only do these forms, viewed in their entirety, correspond, but even their mode of genesis is identical.

The vertebra (A) is a symmetrical form, consisting of opposite laminæ (*c*, *c*), which

join each other at the common median line (*a*, *b*). From these laminæ we find jutting out laterally the exogenous transverse processes (*d*, *d*), each of which is tipped by an epiphysis.

The pair of scapulæ (B) forms a symmetrical figure: both scapulæ (*c*, *c*) are evidently similar to each other, and also to the laminæ (*c*, *c*) of the vertebra (A).* From each scapula we find projecting laterally an exogenous

Fig. 489.



Showing that the pair of scapulæ and the pair of iliac bones, compared with the pair of vertebral laminæ, prove a homological relation, and also that the heads of the humerus, the femur, and the rib are similar to one another.

process (*d*, *d*), which is commonly named acromial process, and each is tipped with an epiphysis also. These acromial processes evidently correspond to the transverse processes (*d*, *d*) of the vertebra (A).

The pair of iliac bones (C) likewise forms a symmetrical figure when laid crest to crest. These two iliac bones (*c*, *c*) are homologous, not only to each other, but to the two scapulæ (B), and to the two vertebral laminæ of A. From each iliac bone there projects laterally the process *d*, *d*, which answers to the acromion process *d* of B, and to the transverse process *d* of A. The process *d* of C is named anterior inferior process of the ilium, and it is tipped with an epiphysis.

The law of symmetry becomes the exponent of the structural identity existing between the figures A, B, and C; for we find the common median line (*a*, *b*) bisecting them through their conjoined bases. The opposite halves of each of these figures form symmetrical figures, but it is also true that the half of each is asymmetrical.

Now, as the rib (*e*, *f*) articulates with each side of the vertebra (A), and is overhung by the transverse process (*d*), so the humerus (*c*, *f*) articulates with each side of the scapular form (B), and is overhung by the acromion process (*d*). In just the same relations, the thigh-bone (*c*, *f*) of the iliac form (C) is overhung by the anterior inferior spinous process (*d*). It becomes evident, therefore, that the heads of the rib, the humerus, and the femur correspond; and this correspondence is manifested, not only by the position occupied by each, but likewise by the genetic character of all three; for the parts of the rib (*e*, *f*) of A are epiphyseal, the same of the parts (*c*, *f*) of the humerus of B, and the same of the parts (*e*, *f*) of the femur of C. The articular facets (*f*) of the rib, the humerus, and the femur correspond; the tuberosity (*e*) of the rib, the humerus, and the femur likewise correspond. The spinous borders of the opposite vertebral laminæ of A, the basis of the scapulæ (B), and

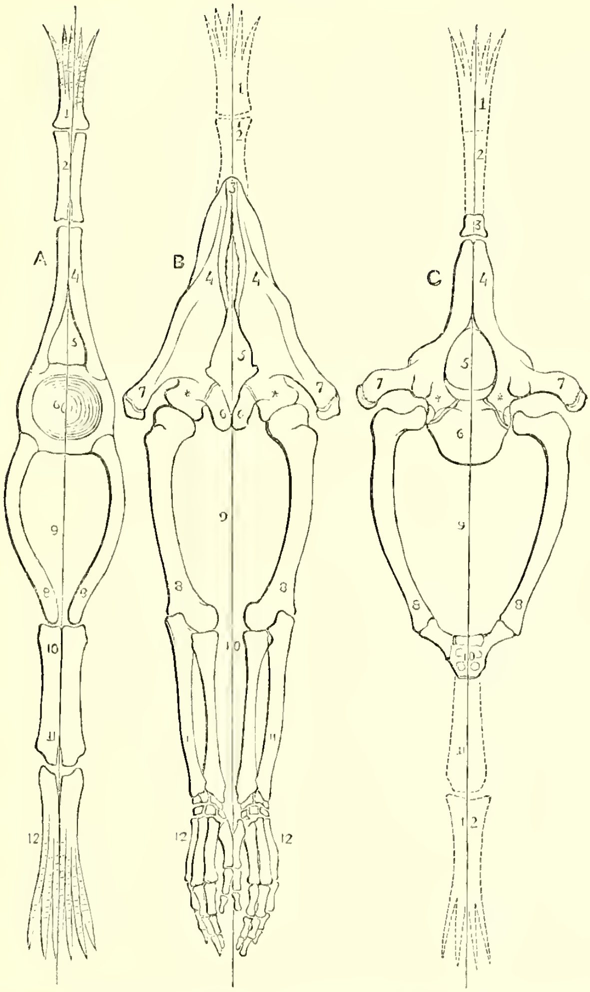
* If this homological relation which I point out as apparent between the pairs of scapulæ and iliac bones, with the pair of vertebral laminæ, be true, then the homological relation which Professor Owen describes as existing between the scapulæ and the ribs, as also between the iliac bones and the ribs, cannot at the same time be received as a true doctrine.

the crests of the iliac bones (C) are bordered with epiphyses; and this also illustrates a similarity between them.

Now, having before demonstrated the fact that the sterno-costo-vertebral quantity was a proportional of the dorso-ventral archetype, it must follow that, while a structural homology exists between the scapulary or pelvic pairs and the costo-vertebral quantity, so, likewise, should the limbs themselves prove to be the proportionals of the dorso-ventral archetype; and this we shall next consider.

In *fig.* 490. I represent the dorso-ventral archetype (A), the scapulary pair of members

Fig. 490.



Showing the homological relation between the dorso-ventral archetype (A), the scapulary organs (B), and the sterno-costo-vertebral quantity (C), and that the difference between these three figures is merely quantitative.

(B), and the sterno-costo-vertebral quantity (C). What are the corresponding points and the differential characters between these three figures? Is the difference between them one of quantity merely? Evidently it is so, and therefore I have marked the corresponding parts of each with the same letter.

In the dorso-ventral archetype (A), the laminæ (4) enclose the neural space (5). In the symmetrical form, constituted of both scapulary limbs (B), the opposed scapulæ (4) enclose the space (5) between them. In the sterno-costo vertebral form (C), the laminæ (4) enclose the neural space (5).

In A we find the ventral arches 8 (call these either hæmal arches, costæ, or what you will) enclosing the ventral space (9). In B the symmetrical humeri (8) enclose the space 9. In C the opposite ribs (8) enclose the space 9. In A the neural laminæ (4) and the hæmal laminæ (8) project dorsad and ventrad from the centrum (5). In B the scapulæ (4) and the humeri (8) project in the same way from the coracoid bodies (6), which I consider

to correspond with the bisected vertebral centrum (6) of A. In C the laminæ (4) and the ribs (8) project in the same way from the centrum (6). In C the transverse processes (7, 7) project from the laminæ (4), just in the same relative position as the acromion processes (7) project from the scapulæ (4 of B). In A there are no processes corresponding with these; but we should recollect that these processes are merely apophyses, and not as distinct elementary constituent parts of the vertebral quantity.

In A the symmetrical hæmal spines or ossicles (11) correspond to the bones of the fore-arm (11 of B). In C the ribs (8) unite at the sternal median line (10), and the ossicles (11) are not existing.

In A the ventral ray is terminated by the palm 12, which is symmetrical; while in B the scapulary members are terminated by the palms 12, which are also symmetrical. These palms are lost at the point 12 of C.

When we compare A with B, we find that all their parts correspond, except in this particular, viz. that A produces dorsad the bones 2 and the palms 1. In B these parts are lost. When, again, we compare C with A, we find that the parts 1 and 2, as well as the parts 11 and 12, are lost to C. It is this loss of quantity which differences B and C from A.

The existence of the parts 1, 2, 4 at the dorsum, and of the parts 8, 10, 12 at the ventrum of *fig.* A., renders this *fig.* symmetrical and equal at the back and venter. The obliteration of the parts 1 and 2 at the dorsum of B renders the figure unequal as to back and venter. But the loss of the parts 1 and 2 from the dorsum of C, and the parts 11 and 12 from its venter, leaves this form still similar as to back and venter, although unequal to the dorso-ventral archetype (A). This difference is merely quantitative.

Notwithstanding this quantitative variety between *figs.* A, B, and C, we still find them symmetrically cleavable by the common median line, and this circumstance points to their analogy. *Fig.* A. is a dorso-ventral limb; *fig.* B. is a ventral limb; *fig.* C. is a ventral costiform limb; and it is a remarkable fact that this latter quantitative form, though usually performing those motions which are required in the act of respiration, is, in some species of animals (the ophidian and the lizard), operative as a locomotive member.

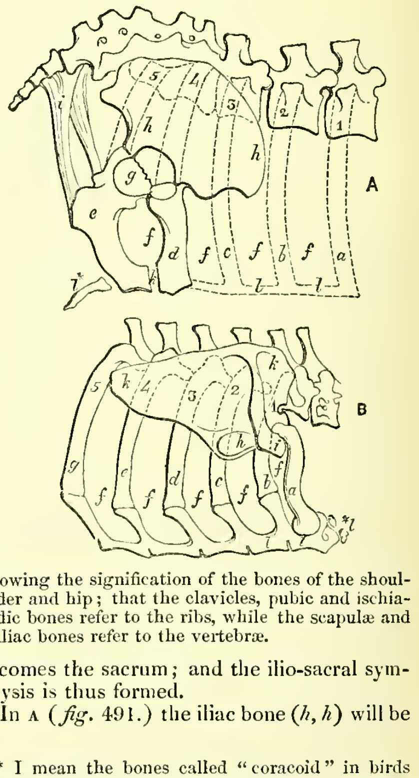
Fig. A. encloses neural and hæmal space at the points 5 and 9, and stands in spinal series with all its fellows of that series. It is an archetype compounded of the parts called vertebra; at the dorsum and venter of which stand the parts called the limbs. *Fig.* B. is a proportional quantity of such another archetype as A; and having suffered bicleavage through its median line, it falls asunder on either side of the animal, and encloses the thorax between its opposite halves, at the space 5, leaving the prehensile organs, consisting of 8, 11, 12, playing freely on either side of the body. *Fig.* C. is a proportional quantity, also of such another archetype as *fig.* A, and stands in spinal serial order with this latter, enclosing neural and hæmal space at the points 5 and 9. The spinous ossicle (3) which surmounts the laminæ (4 of C), is part of the quantity marked 2 in A, the archetype. The spinous ossicle (3 of C) and the epiphyseal nucleus (3 of B), which borders the bases of the two scapulæ, correspond.

When *fig.* C. forms the sternum (10) by a union of the ribs (8, 8), this sternal line in all animals may be regarded as that median place where the archetypal quantity (11 and 12) is lost; and in the same way, when C forms the spinous union at the dorsum, surmounted by the bilateral spinous ossicles (3), this spinous point of the skeletal axis of all animals may be said to be that place where the archetypal quantity (1 and 2) has been subtracted.

The mode in which the vertebriform scapulæ contract a connection with the costiform clavicles and coracoid bones*, is similar to the mode in which the vertebriform iliac bones become joined to the costiform pubic, and ischiadic bones, as a reference to *fig.* 491. will prove.

When the two iliac bones, to which are appended the hind limbs, fall from vertebral spinal series, bicleft on the animal's sides at the lumbar region, they abut on either side of that region of vertebral series, which hence

Fig. 491.



Showing the signification of the bones of the shoulder and hip; that the clavicles, pubic and ischiadic bones refer to the ribs, while the scapulæ and iliac bones refer to the vertebræ.

becomes the sacrum; and the ilio-sacral symphysis is thus formed.

In A (*fig.* 491.) the iliac bone (*h*, *h*) will be

* I mean the bones called "coracoid" in birds and reptiles, not the mammal coracoid processes, for I have already named these latter to be the bicleft centrum of the scapular vertebra.

observed to occupy the interval between (e, d) the ischiadic and pubic bones, and (3, 4, 5) the sacral vertebræ. The junction between the ilium and the sacral vertebræ is called sacro-iliac, whereas by the union of the ilium (h,h) with the pubic and ischiadic bones (d,e), the articular cup called acetabulum (g) is formed. While the ilium becomes thus intercalated between the pubic and ischiadic bones on the one hand, and the vertebræ on the other, it severs the former from connection with those vertebræ to which, as costæ, they properly belong; and it obliterates that costal quantity indicated in dotted outline at 3, 4, 5, which quantity, if it still persisted, would unite the pubis and ischium to their proper vertebræ. In *fig.* 491. I have represented in A some of those lineæ transversæ (a, b, c), which sketch out the form of the original ventral ribs proper to the lumbar vertebræ; and it will be seen that a, b, c hold series with (d) the pubic bone, and (e) the ischiadic bone. Between a, b, c, as the ventral ribs, occur the intercostal spaces (f, f), and between the pubic and ischiadic bones (d, e) occurs that space (f) which, in human anatomy, is named "thyroid foramen." Is not this thyroid foramen an intercostal space, if d and e be costæ proper to the sacral vertebræ? And do not the pubic and ischiadic symphises at the point k correspond to the linea alba (l, l), which stretches between the pubis and sternum?

In *fig.* B. we find the scapula (k, k, h, i) occupying, at this region of series, a position similar to that which the iliac bone holds elsewhere. But beneath the scapula the ribs (2, 3, 4), for obvious purposes, persist; while beneath the iliac bone they are wanting. This want of the ribs beneath the iliac bone, and this presence of the ribs beneath the scapula, constitute the difference.

If those portions of the ribs (b and c of *fig.* B.) which lie beneath the scapula suffered metamorphosis, then b and c would abut upon the glenoid cavity h, and would be to the scapula what the pubic and ischiadic costiform bones are to the ilium; and then we should have, between b and c of *fig.* B., the intercostal space f, as corresponding to the thyroid aperture. It is the costiform clavicle (a of B) which becomes severed by the scapula from its vertebra behind, just as the costiform os pubis is severed by the iliac bone from its vertebral quantity.

The cotyloid cavity (g of A) is formed by the junction of three bones, viz. the ilium (h h), the os pubis (d), and the ischium (e); but it is the iliac facet of the cotyloid cavity which alone corresponds to the glenoid cavity of the scapula. If the ribs (b or c of *fig.* B.) happened to be dissevered from their vertebræ behind by an interval equal to the size of the scapula (k, k, h), and if these sternal ends of the ribs (b, c) then joined themselves to the glenoid articular surface (h) of the scapula, the three bones (h, b, and c) would also form a cotyloid cavity for the head of the humerus.

In those animals (birds, reptiles, &c.), where two clavicles are required to be metamorphosed from ribs, they illustrate still further the structural analogy which exists between them and the ischiadic and pubic bones, which latter exhibit, in relation to the ilium, the same character that the clavicles manifest in relation to the scapula.

In *fig.* A. the os penis (l*) will be seen to fall behind the symphisis pubis, while in *fig.* B. the episternal ossicles (l*) will be noticed as producing the sternal median line forwards into the neck. At the subpubic region, where l* occurs, and at the episternal region, where the episternal ossicles occasionally appear, the sternal median line is bounded in the animal; but in the comparative abstract animal, these points may be regarded as unfinished.

Prop. XLIV. *The cranio-facial apparatus of segments are proportionals of the dorso-ventral archetypes.*—If it be true that the vertebral quantity is a proportional of the sterno-costo-vertebral quantity, and this latter a proportional of the dorso-ventral archetype, then it must follow that the cranio-facial apparatus, which appears to bear a structural homology with the sterno-costo-vertebral quantities, is also constituted of segments which, like these latter, are proportionals of the archetypal quantities. Even though the whole animal kingdom did not present us with a skeletal form, upon whose cranium the dorsal rays persisted complete, still the above-mentioned inference may be legitimately drawn; but when, amongst the class of osseous fishes, we find *fig.* 492., upon whose cranium the dorsal rays actually persist, then the *à priori* and the *à posteriori* trains of reasoning meet and answer to each other, while standing in presence of the fact itself, as nature produces it.

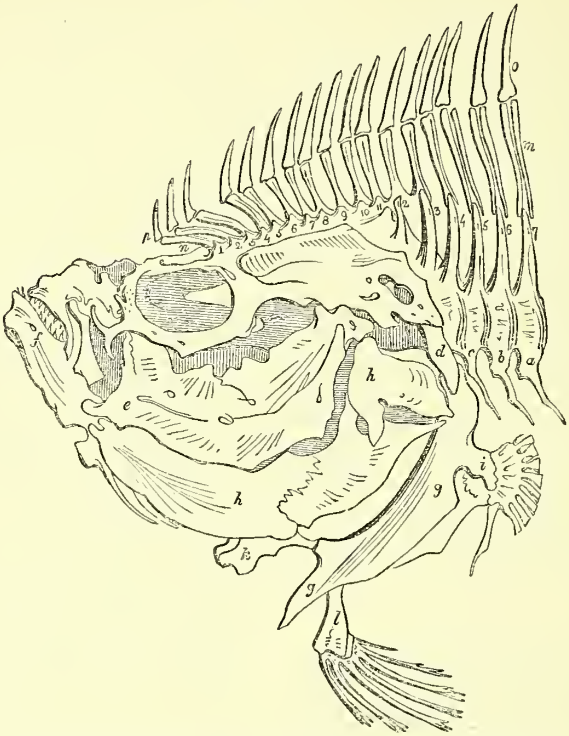
In *fig.* 492. we see that the archetypal dorso-ventral quantities (a, b, e, d) are continued into the head, not only by their centra, their costal inferior arches, and their dorsal laminæ, which form the neural arches from 17 to 1, but also by their dorsal interspinous ossicles from m to n, and by their dorsal palms from o to p.

The head of the osseous fish (*fig.* 492.) of the class Pleuronectidæ may be accounted, therefore, as constituted of a series of the dorso-ventral archetypes specially modified. Between the cranial and the facial structures is continued the line of spinal centra; and from these, as from the centra elsewhere throughout spinal series, the dorsal and the ventral rays project. The inferior cranial rays are the jaw-bones (e f, h h) and hyoid arches (g, g); the superior cranial rays are the forms o p, m n.

Prop. XLV. *The cranio-facial apparatus is the origin of the dorso-ventral archetypal series, and the caudal apparatus is its termination.*—In the same animal, whose cranial structures are still crested by the dorsal rays complete, we find the opposite caudal extreme (*fig.* 493.) also crested by similar rays, dorsad as well as ventrad. The spinal centra (n, m, l—a) still produce the entire rays (o, q) above and below, while the terminal centrum (a) stands as

a nucleus, around which are arranged, in palmate order, the rays of nine archetypes, which, bending towards each other, and to the horizontal ray (9), fashion the fan-shaped caudal fin. This caudal fin, whose rays describe the arc P Q, is composed of the palms of nine arche-

Fig. 492.



The cranio-facial apparatus of the osseous fish (Pleuronectidæ),
Indicating the metamorphosis of twelve or more spinal quantities in its composition.

types, radiating from the common centre (a). The nine inferior palms are those which number from 17 to the palm 9; and the nine superior palms are those which number from 1 to the palm 9; while the azygos palm 9 may be regarded as composed of the dorsal and ventral palms of the last archetype bent towards each other, and becoming in the horizontal line fused together. The bones (o, p, q), are the counterparts of the neural and hæmal laminar arches, assuming the same palmate order as the palms. The head (*fig.* 492.) and the caudex (*fig.* 493.) constitute the origin and termination of spinal series, and are examples of special modifications exercised upon the original archetypal quantities.

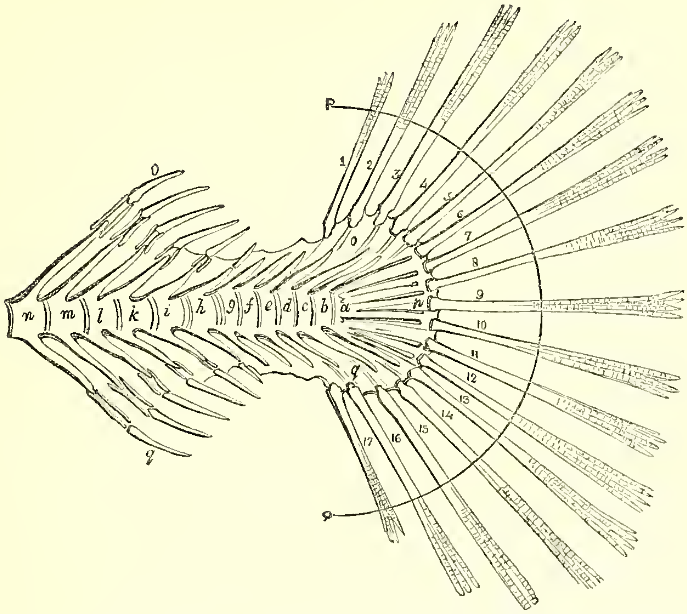
Prop. XLVI. *The uniform archetypal series undergoes a graduated metamorphosis of its quantities for the production of all varieties of skeletal species.*— In *fig.* 494. I represent the archetypal series of the dorso-ventral quantities constituting the uniformity, forasmuch as all the segments are plus and quantitatively equal. The segment 1 is equal to the segment 38, and to all the intervening segments. This uniform series of quantities appears finite, like the right line (C D) which passes through its centre; but as the right line itself is but a part or proportional of that ideal line which is infinite or boundless, so of the series of archetypal quantities, numbering in the figure from 1 to 38; for this series may like number be produced to infinity in imagination.

In the serial line (*fig.* 494.) which is composed of 38 archetypal dorso-ventral quantities, we do not as yet distinguish any special differences; and this is owing to the fact that all the quantities composing the series are similar or homologous; neither can we discover any reason why we should name either of the extremes of this serial line (D C) as the origin or the termination in preference to the other extreme, for the segment 38 is equal to the segment 1; and hence it matters nothing to the entities themselves at which end of the series we commence the enumeration. In nature there is no instance of a skeletal axis constituted of such a uniform serial line of quantities as those of *fig.* 494., but yet it is possible to prove that every skeletal axis is part of such an original series. That skeletal axis which approaches nearest to the absolutely uniform condition of *fig.* 494. is to be found amongst the class Pisces.

The skeletal fabrics of all animals are sym-

bolic of that sphere in Nature in which they are destined to live and act. The two main primary divisions of differential forms are those of aquatic and terrestrial animals. The aquatic class, inhabiting the watery regions, symbolise their native element, in which

Fig. 493.

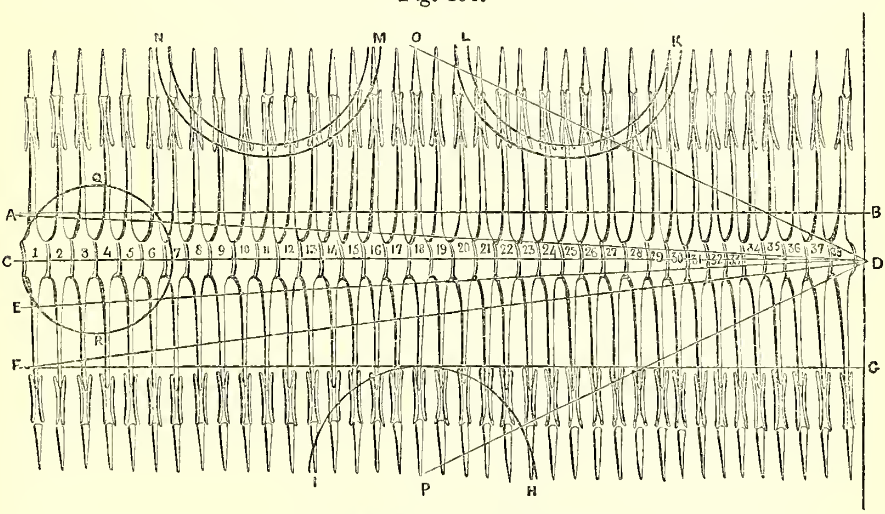


The caudal apparatus of the osseous fish (Pleuronectidæ).

they move submerged; and accordingly we find them treading this medium by locomotive members arranged dorsad as well as ventrad; while the terrestrial class, moving prone upon the earth, produce the locomotive organs suited to that motion, viz. on the ventral side only.

All species of the class of fishes approach

Fig. 494.



The uniform archetypal spinal series,

Showing how the species or variety is proportioned from it as the plus quantity.

nearer to the plus uniform character of the serial axis (*fig.* 494.) than any of the species of the terrestrial class; for all species of the former class produce some form of the locomotive or fin member dorsad, whereas no species of the terrestrial-moving class requires any form of such a member. Even the mammalian cetaceans are furnished with a remnant

of the dorsal fin, since they are denizens of the world of waters. The tribe of fishes known as Pleuronectidæ is bordered dorsad as well as ventrad by the locomotive palm-organs, and therefore they simulate the series of *fig.* 494. more closely than any other class of animals. The Pleuronectidæ are the most archetypal class of animals in Nature; for the first step of the law of formation in the metamorphosis of *fig.* 494. is to create a cephalic end (*fig.* 492.) and a caudal end (*fig.* 493.) to this series of whole quantities, by a modification of a certain number of the archetypes at either end; and thus the animal of the class Pleuronectidæ is fashioned, having the continuous palmed or fin-organ still persisting dorsad and ventrad on those spinal archetypes which stand in series between the cephalic and caudal extremes.

The structural composition of the head will vary according to the number of those serial archetypes which suffer metamorphosis for its creation. For if we suppose that the six quantities which are included within the circle Q C R (*fig.* 494.) should be subjected to cephalic metamorphosis, we still can assign no reason why Nature should limit herself to the number *six*, or any other number, if necessity required the metamorphosis of a greater number for one species of cephalic apparatus and a less number for another. Although in a former place I have numbered six segments as proper to the composition of the human head, still I am by no means of opinion that Nature limits herself to number six in the creation of all other species of cephalic apparatus; on the contrary, I shall not hesitate to assert it as a fact, that (*fig.* 492.) the head of the plaice may be taken as an instance in which fourteen dorso-ventral archetypes have suffered cephalic modification.*

The alternate fin-organs at the back and venter occur by the alternate metamorphosis of certain members of the palms of the continuous series of archetypal quantities. In the Pleuronectidæ, the dorsal and ventral palmed fins are continuous for the entire length of the spinal axis, as in *fig.* 494.; but in other classes of fishes we find the fins occurring isolated at certain regions of the spinal axis: such, for example, as the fins called dorsal, jugular, abdominal, anal, and caudal; and this alternation may be explained by referring to *fig.* 494. If the palms which I have included in the semicircles K L, M N happen to be metamorphosed or subtracted, then the isolated dorsal fin (M O L) will remain as we find it presenting in many of the class Pisces, and even in some of the cetaceans. The fin-organ is composed in all cases of a plural number of palms; the number always corresponding to the dorsal rays of the archetypes. The palm is a hand, while the fin presents as a series of hands.

When the series of archetypal quantities suffers metamorphosis at certain lines which the creative hand of Nature draws through it, the animal design or species is struck out accordingly. When all quantity lying external to the converging lines O D, P D undergoes metamorphosis or subtraction, then the series of quantities which happens within these lines will exhibit the condition of proportional and progressional quantities, such as we find standing in the caudal region of many animals. When Nature draws the right line A B through this region of the serial archetypes, and at the same time metamorphoses all quantity above or dorsad to this line, she creates the dorsal region of the spinal axis of all terrestrial animals, to which are remaining those parts which we name the neural arches, sufficient for the protection of the spinal cord.

The quantity which occurs within the lines A B, F G answers to the thoracic ophidian skeletal axis, whose ventral or opposite costal arches occur by a bicleavage of the azygos ventral rays. The thoracic series of each skeletal axis is formed after the same manner as that of the ophidian. The numerical length of every thorax varies according to the number of those serial archetypes of *fig.* 494. which suffers thoracic metamorphosis; and its position in spinal series varies also according to the numerical position of those archetypes which undergo a thoracic modification; for if they be the segments which hold serial order between that which numbers (in *fig.* 494.) as 13, and that which numbers 30, then the thoracic length will correspond to these numerical segments.

When the head is fashioned of the six quantities included in the circle Q C R, while the neck is proportioned by the line E D, from six, or seven, or more of those quantities which succeed the head, viz. those segments between 7 and 14, 15, or 16, then the neck will number accordingly; and when the thorax is to succeed the cervix, then the twelve or more segments which succeed those of the cervix are proportioned thoracically by the lines F G. When, lastly, the lumbar, sacral, and caudal regions are to succeed the thorax, it is the line F D which gives to these regions their several quantitative characters.

The law of "unity in variety" appears therefore to be plainly demonstrable as an archetypal plus series of quantities, undergoing a graduated metamorphosis; and if, by the order of the foregoing remarks, I have left upon the reader's mind the idea that the proportional variety constitutes the species of one form of skeleton compared to another, and to all others of the four classes of vertebrate animals, then my object has been attained by the course of argument which I have pursued.

(*Joseph Maclise.*)

* Professor Owen enumerates four vertebral segments as composing the heads of all animals of the four classes. For my own part, I see no reason to entertain the opinion that Nature limits herself to a fixed number in the segments of the head, any more than she does in constructing the cervix, the thorax the loins, the sacrum, or the caudal region of the spinal axes. Carus and Oken speak of the number *five*, as though Nature limited the operation of her law in patronage to this magical *quinque* in vertebrate creation.

SLEEP.—This term is employed to designate that state of suspension of the sensory and motor functions, which appears to alternate, in all animals, with the active condition of those functions, and which may be made to give place to it by the agency of appropriate impressions upon the sensory nerves.

Although this may seem a complex definition of a state which seems to be in itself so simple, yet it will not be found easy to alter its character without rendering it less stringent. We more especially desire to exclude from it the abnormal condition of *coma*, in all its forms; whether resulting from the influence of pressure or effusion within the cranium, or consequent upon the poisoning of the blood by narcotic substances, or occurring as part of that inexplicable series of phenomena which are termed hysterical. The state of coma, where not so intense as to affect the movements of respiration and deglutition, is identical with profound sleep as regards its obvious manifestations; but there is this important difference, that simple sleep may be made to give place to activity by the application of appropriate stimuli to the sensorial system; whilst in complete coma, no impressions on the sensory nerves have any power of bringing back the consciousness. Between these two conditions, however, every gradation may be seen; as in the heavy sleep produced by an over-dose of a narcotic, in incomplete hysteric coma, or in the torpor resulting from slow effusion within the cranium.

The necessity for sleep seems to arise from the fact, that the exercise of the animal functions is in itself destructive of the substance of the organs which minister to them; so that, if the waste or disintegration produced by their activity be not duly repaired, they speedily become incapacitated for further use. This doctrine is now so generally admitted, that it does not seem requisite to adduce proofs in its support. The substance of muscles is regenerated during the suspension of their action in simple repose; and it is not essential that, for this purpose, a state of unconsciousness should intervene. As the substance of the nervous centres and trunks, more especially the former, undergoes a similar disintegration as a necessary consequence of its activity, this too requires a period of repose for its regeneration; but the repose, or suspension of functional activity, of the sensorial portion of the nervous system, necessarily involves unconsciousness; and it appears to be on the *nutritive regeneration* which takes place during true sleep, that its *refreshing* power depends. No such refreshment is experienced from the unconsciousness of coma, however prolonged; and there are some forms of ordinary slumber in which it is more or less deficient. The organic functions are not affected in any considerable degree by the suspension of the sensorial; for we find that not only are the operations in which these functions *essentially* consist uninterruptedly carried on, but that the muscles, nerves, and nervous centres also which are concerned in maintaining them, are enabled to sustain an unintermitted action. Thus the movements of the heart are not, in warm-blooded animals at least, normally suspended, from the first development of that organ until the close of life; the respiratory motions, in like manner, are kept up uninterruptedly from birth to death; and the propulsion of food along the alimentary canal during sleep by the peristaltic contraction of its muscular coat, the sustained action of the sphincters, the peculiar position of the eyes, and the active state of the extensor muscles of the legs in animals which sleep standing, are additional evidences that the state of continuous repose is not required for the renovation of the powers of certain parts of the nervous and muscular apparatus. To use Dr. Marshall Hall's phraseology, "the true spinal system never sleeps;" and, whatever we may think of the existence of his "true spinal" system of nerve-fibres, as distinct from those which minister to the functions of the encephalon, there can be no longer any doubt that the ganglionic portion of the spinal cord is a distinct centre of nervous action, which retains its power of actively responding to impressions made upon it, during the profoundest repose of the other centres; whilst, from the complete suspension of its functions, even for a very brief period, death inevitably results.

In following out our inquiry into the nature of sleep, and of certain conditions allied to it, we shall find it convenient to regard the encephalon as composed of four leading or primary divisions: 1. The *medulla oblongata*, which essentially consists of a prolongation of the spinal cord, including the centres of respiration and deglutition; and also having incorporated with it, without properly forming part of it, the ganglia of hearing and of taste; 2. The *ganglia of sensation*, including, with the olfactive, optic, auditory, and gustative centres, the corpora striata and thalami optici, which are probably, when taken together, to be regarded as the ganglia of tactile sensation*: 3. The *hemispheric ganglia* (Solly), or peripheral portion of the *cerebral hemispheres*: and 4. The *cerebellum*.

The *first* of these divisions really belongs to the spinal cord, and, like it, is constantly active.—The *second* appears collectively to form the true *sensorium*, to which external impressions must be conveyed, in order that they may be *felt* (each class of sensations being received through the medium of its own ganglion), and from which proceeds the stimulus to those automatic movements which can only be excited by a sensation. Such are the truly *instinctive* actions.—The *third* division, of which scarcely a rudiment exists in the lowest fishes, although it constitutes by far the largest proportion of the encephalon in man, seems to be the instrument through which *ideas* are generated, by which they are retained and made the subjects of intellectual

* See British and Foreign Medical Review, vol. xxii. p. 510.

processes, and by which voluntary determinations are formed. Impressions made upon the organs of sense would seem only able to act on the hemispheric ganglia through the medium of the sensorium; whilst the voluntary determinations, resulting from the exercise of the reasoning powers, can only act on the muscular system by the transmission of a downward impulse from the hemispheric ganglia to the automatic centres, in which the motor nerves originate.

If this be a true representation, the ordinary phenomena of sleep are not difficult of comprehension. The state consists essentially in suspended activity of the *sensorium*, so that impressions made on the organs of sense are neither *felt* nor *perceived*,—that is, neither excite sensations, nor give rise to ideas. In like manner, those automatic movements which are dependent upon sensations for their excitement are suspended; and as the torpor of the sensorium cuts off the functional connection between the hemispheric ganglia and the muscles, the latter cannot be called into activity by any mental operations in which the former may be concerned. In ordinary profound sleep, the hemispheric ganglia would seem to be in the same passive condition as the sensorium itself; so that *all* mental activity is suspended. In dreaming, however, there is a train of ideas, called up by the laws of association, and not regulated by any voluntary control, bespeaking a partial activity of the hemispheric ganglia. Into the conditions of this phenomenon we shall inquire hereafter; at present only observing, that if the sleep be deep, external impressions are as completely unperceived by the dreamer, as they are in a state of entire unconsciousness; and that, in like manner, the strongest desire felt by the dreamer to perform certain bodily movements, even when he fancies that his life depends upon them, is as ineffectual as if he were suffering from a total paralysis. If external impressions are in any degree felt by the dreamer, or his volition can exert its power over the movements of his body, the sleep is not profound, but rather approximates towards the state of somnambulism or sleep-waking, in which the sensorial as well as the hemispheric ganglia are in a condition of partial activity.

The state of simple sleep, again, is allied to that of hibernation (*see* HIBERNATION); the difference between them being essentially this, that in the latter condition, besides the profound torpor of the sensorial centres, there is a great diminution or complete suspension of the activity of the organic functions. We may trace, in fact, every gradation between the simple repose of the sensorial centres, in which the state of sleep essentially consists, to that complete suspension of all the functions of life, which is of ordinary occurrence, during the winter season, in cold-blooded animals. Many of these can even endure the freezing process without the loss of their vitality; their activity being restored by the renewal of warmth. Next to this is the condition of those hibernating mammalia, which pass the winter in a state of uninterrupted torpor, and in which the organic functions seem reduced to their lowest possible amount of activity, short of entire stagnation. This reduction is manifested in the slowness of the circulation, the infrequency of the respiratory movements, the low degree of heat sustained, the abatement of the demand for food, and the small amount of carbonic acid, urea, and other excretory products, set free during the persistence of the hibernating state. But there are other hibernating mammals, in which the reduction is less decided, and the torpor less profound; these animals awaking from their repose at long intervals, taking food from the store which they have prepared, and again relapsing into inactivity. And there are others, again, in which it differs but little from ordinary profound sleep, except that the proportion of time passed in the waking state is much less than usual. Further, it is a curious observation of Dr. M. Hall's (loc. cit.), that the ordinary diurnal sleep of certain hibernating mammalia presents, in the reduced activity of the organic functions, an approach to the torpor of their winter state.

Sleep of Plants.—The complete suspension of the *organic* as well as of the *animal* functions during the hibernation of cold-blooded animals corresponds with what has been termed the *winter sleep* of plants. But plants have also what has been called a *diurnal sleep*; and although it is obvious that plants can present no phenomena really analogous to those in which we have defined the sleep of animals to consist, yet there are periodical changes in the condition of their leaves and flowers which are deserving of consideration under this head, especially as affording ing an additional indication that even in the functions of organic life there is a tendency to a more or less decided alternation of activity and quiescence. The parts of plants which exhibit the changes in question, are the *leaves* and the *flowers*. In the former we frequently notice an entire difference in the nocturnal and diurnal aspects of the leaves, which is the result of a periodic change, affecting either the position of the leaf as a whole, or that of the several leaflets of which a compound leaf is formed. The petioles, or stalks of the leaves or leaflets, either bend upwards or downwards; so that the flattened surface of the leaf is either elevated or depressed. This is not a result of simple flaccidity; for, as De Candolle remarks *, the nocturnal position is maintained with the same rigidity and constancy as the diurnal; so that the "sleeping" leaf would be broken, more readily than it could be forced into the position which is proper to it during the day. Eleven different modifications are enumerated by the distinguished botanist just cited, in the manner in which the leaves incline themselves to the stalks on which they grow. Thus, of the entire leaves which exhibit this phenomenon, some sleep face to face, others back to back,

* Physiologie Végétale, p. 855.

others fold in at the sides so as to embrace the stem or to protect the flower which arises from their axil. It is rare to see a movement of the whole of a compound leaf, when its individual portions fold together; such a movement is seen, however, in the *Mimosæ*. The variety of positions assumed in sleep by the subdivisions of compound leaves is very considerable, and need not be here enumerated: the phenomenon is best exhibited by the *Leguminosæ* and the *Oxalideæ*.

Of the causes of this phenomenon, little can be definitely stated. They are not to be looked for solely in the operation of external physical agents, such as light, heat, and moisture; for it can be easily shown that the changes in question cannot be thus accounted for, without attributing to the plants by which it is exhibited a tendency to such periodical manifestations inherent in their own constitution. Thus, when sensitive plants are confined in a dark room, their leaflets periodically fold and open as usual; the periods, however, being somewhat lengthened. On the other hand, when exposed to continued light, the periodical folding and unfolding still occurs, but the periods are shortened. And when the plants are exposed to strong lamplight by night, and excluded from all light by day, their periods of sleep become extremely irregular for a time, but in the end the plants generally close their leaves during the day and open them at night. No such modifications can be induced, however, in the *Oxalideæ;* their periods of opening and closing their leaves being unaltered by light, darkness, or by the disturbance of the natural sequence of the two. In the same manner it may be proved that these movements cannot be laid to the account of changes of temperature; for it appears from the experiments of De Candolle, that they continue to take place in plants exposed to various degrees of temperature, as well as in those left in air, provided that the heat or cold be not sufficient to injure the health of the plants. And by the same method of exclusion, they can be shown not to be dependent upon variations in the amount of circumambient moisture; since they continue equally well, *cæteris paribus*, when plants are kept in stoves the humidity of whose atmosphere is uniform, and in some cases even when the plants are entirely immersed in water. We must conclude, then, that although the exact time of the occurrence of the phenomenon may be liable to modification from the influence of external agents, its performance is essentially independent of them, and must be referred to causes inherent in the plant itself.

The periodical closing of *flowers* is a change which is obviously analogous to the sleep of leaves. Many flowers only expand themselves once, and speedily wither. Even in this case, however, there is often considerable regularity in the time of expansion, indicating periodicity. But in the flowers which remain fresh for some days, some degree of alternation between closure and expansion may be generally discerned. There is no definite relation, however, between the sleep of flowers and that of leaves; for they may be united in the same individuals, or be exhibited separately in different species of the same genus. Among other curious examples which show the absence of connection between the two classes of phenomena, is one cited by De Candolle from Berthollet; the subject of it being an Acacia cultivated in the garden at Orotava, in which the leaves closed at sunset, but the flowers then expanded, their numerous stamens raising themselves up like tufts of feathers, so as to become conspicuous; whilst in the morning, when the leaflets assumed their diurnal position, the filaments relaxed so that the bunches of stamens gave to the flowers the appearance of floss-silk, and the flowers themselves partly closed together.

It has been ascertained by Meyen, that, by the action of artificial light and darkness, the usual hours for opening and closing may be changed in flowers as well as in leaves. Thus he found that after passing two days in a room from which external light was excluded, but which was lighted by four Argand lamps, the flowers of *Ipomœa purpurea*, which naturally open during the night, expanded in the morning; whilst those of *Oxalis tetraphylla*, at the end of the fourth day of artificial illumination, opened in the evening, instead of at their usual morning hour.

Periodicity of Sleep. — There can be little doubt that a tendency to occasional repose is inherent in the constitution of every animal possessed of a sensorial apparatus; and that this disposition is so arranged as to correspond in its periodical recurrence with the diurnal revolution of the earth. Although we are accustomed to think that "night is the time for sleep," and although, in our own case and in that of most other animals, darkness and silence favour repose, yet it must be borne in mind that there are many tribes of animals whose period of activity is the very same with that during which most others are wrapped in slumber. Thus, among lepidopterous insects, we find the activity of the greater part of the butterflies to be diurnal, that of the sphinges to be crepuscular, and that of the moths to be nocturnal. So among the insectivorous birds, we find the diurnal swallow replaced during the night by the goatsucker (or night-jar); whilst the insectivorous bats are most active during twilight. Among the raptorial birds, again, we find the whole tribe of owls, with only one or two exceptions, to be either nocturnal or crepuscular in their activity. And among carnivorous animals we meet with a similar diversity. As a general rule, the vegetable-feeders of all tribes are diurnal in their activity, taking their repose at night. The nocturnal predaceous animals take their repose during the day; and those whose period of activity is the twilight, sleep partly by night and partly by day.

Notwithstanding this variety as to the periods of sleep and activity, the complete

cycle in every case is fulfilled in twenty-four hours; and this uniformity in their recurrence would seem to indicate either an *entire* and invariable dependence on external agencies, or else a periodical tendency to sleep, inherent in the animal kingdom, and corresponding with the cycle of day and night. The experience of the human species seems to be decisive in favour of the latter view.

There is, among all tribes of mankind, a general uniformity in the periods of slumber and activity, which is scarcely inferior to that observable among the lower animals; yet we find reason to believe that this periodicity is a law of our own organic constitution, for it is quite certain that it cannot be seriously departed from without injury to the system, and that, even where light and warmth are continuous through the whole range of the twenty-four hours (as during the summer in arctic regions), the same periodical desire for sleep manifests itself, resistance to which is prejudicial to the health. As Dr. Whewell justly remarks* — "No one can doubt that the inclination to food and sleep is periodical, or can maintain, with any plausibility, that the period may be lengthened or shortened without limit. We may be tolerably certain that a constantly-recurring period of forty-eight hours would be too long for one day of employment and one period of sleep, with our present faculties; and all whose bodies and minds are tolerably active will probably agree, that, independently of habit, a perpetual alternation of eight hours up and four in bed would employ the human powers less advantageously and agreeably than an alternation of sixteen and eight." We may remark, however, that when the habit has been once acquired, the *shortening* of the cycle is probably not so injurious as its *extension*. We know by experience that the habitual attempt to sustain an uninterrupted activity during more than sixteen or eighteen hours at a time, is either unsuccessful, or, if successful, is very wearing to the system. On the other hand, the experience of seamen who kept "watch and watch" during long voyages without any obvious injury to their health, indicates that if the due amount of sleep be obtained within every twenty-four hours, the division of the cycle is not attended with any prejudicial effect. On the whole, we may conclude with Dr. Whewell, that, "when we have subtracted from the daily cycle of the employments of men and animals, that which is to be set down to the account of habits acquired, and that which is occasioned by extraneous causes, there still remains a periodical character, and a period of a certain length, which coincides with, or at any rate easily accommodates itself to, the duration of the earth's revolution.

Causes of Sleep. — The most potent of all the causes of sleep, which is capable of acting by itself, when in sufficient intensity, in opposition to the most powerful influences tending to the continuance of wakefulness, is the condition of the nervous system induced by its protracted functional activity. Sleep may thus come on in the midst of the roar of cannon, and this not merely in persons accustomed to the noise, but in those who have never previously experienced it. Thus it is on record that during the heat of the battle of the Nile, some of the boys who were over-fatigued fell asleep on the deck. We have known a listener to an orchestral performance drop off in slumber during the noisiest part of the grand finale. Again, the continued demand for muscular activity is not incompatible with the access of sleep. During fatiguing marches, as in the retreat to Corunna, it has been repeatedly noticed that whole battalions of infantry have slumbered whilst in motion; muleteers frequently sleep on their mules, coachmen on their boxes, and post-boys on their horses; and factory children, before the shortening of the hours of work, were often known to fall asleep whilst attending to their machines. Bodily pain, again, yields before the imperative demand occasioned by the continued exhaustion of the powers of the sensorial centres. Of this the medical practitioner has frequent illustrations. It is well known, too, that the North American Indians, when at the stake of torture, will go to sleep on the least remission of agony, and will slumber until the fire is applied to awaken them. It is related that Damiens slept during his protracted tortures upon the rack; and that this having been prevented by the constant renewal of fresh torments, he spoke of the want of sleep, a little before the termination of his existence, as the most dreadful of all the sufferings he had endured. That the strongest voluntary determination to remain awake is forced to give way to the demand for sleep produced by the exhaustion of nervous power, must be within the experience of every one.

It does not appear to be of any consequence whether this exhaustion is produced by the active exercise of volition, emotion, reflection, or simple sensation. In all alike the sensorial centres must participate; by all alike, therefore, must their nervous substance be subjected to that disintegration which cannot proceed beyond a certain point without either being repaired by sleep, or producing a state of exhaustion which becomes fatal. Nevertheless, we find that the involuntary continuance of mental activity is unfavourable to access of sleep, so as to oppose the action of other predisposing influences; and such persistence will be found to be especially difficult to check in cases in which the *feelings* are concerned. The activity of the purely *intellectual* operations, which can be suspended at any moment, provided the feelings be not interested in their continuance, predisposes to sleep instead of preventing it. But the *desire* to work out a result, or to complete the survey of a subject, is an *emotional* state which induces restlessness, remaining active until it is gratified. So, again, anxiety or distress is a most frequent cause of wakefulness; the ex-

* Bridgewater Treatise, p. 40.

citement of the feelings keeping up a *forced* state of mental activity, which no voluntary effort can subdue. The state of *suspense* is in most persons more difficult to bear with equanimity, and is more opposed to the access of sleep, by the continual perturbation which it induces, than the greatest joy or the direst calamity when certainty has been attained. Thus it is a common observation that criminals under sentence of death sleep badly so long as they entertain any hopes of a reprieve; but as soon as they are satisfied that their sentence will be certainly carried into execution, they usually sleep more soundly,—and this even on the very last night of their lives. That the continued excitement of the feelings, whilst producing an indisposition to sleep, really occasions as great a demand for it in the system as is produced by the most active exercise of the intellectual powers, is evident from the very exhausting effects of its protraction; which necessitate a long period of tranquillity for restoration to health.

Among the most powerful of the predisposing causes to sleep, is the *absence* of sensorial impressions: thus darkness and silence usually conduce to repose; and the cessation of the sense of muscular effort, which takes place when we assume a position that is sustained without it, frequently acts as the complement of all other influences. There are cases, however, in which the continuance of an accustomed sound is necessary instead of positive silence, the cessation of the sound being a complete preventive of sleep. Thus it happens that persons living in the neighbourhood of the noisiest mills or forges cannot sleep elsewhere; and when, to induce repose in illness, the mill or the forge has been stopped, the cessation of the sound only occasions more obstinate wakefulness. Such instances, perhaps, fall within the next category of predisposing causes, — namely the *monotonous repetition* of sensorial impressions. Every one knows how efficacious a provocative of sleep is the droning voice of a heavy reader, especially when his subject is equally prosaic. The ripple of the calm ocean upon the shore, the murmur of a rivulet, the sound of a distant waterfall, the rustling of foliage, the hum of bees, and similar monotonous impressions upon the auditory sense, are usually found to induce sleep; and Boerhaave relates, that being desirous of procuring sleep for one of his patients troubled with obstinate insomnia, he directed a brass pan to be so placed as to receive a succession of drops of water, the sound of which had the desired effect. A lulling influence, however, is not universally thus produced; for we have known a case in which sleep was altogether kept away by the sound of dropping water, which seems to have occasioned a state of emotional excitement. Not only is the repetition of auditory impressions provocative of sleep; uniform succession of gentle movements has a similar effect upon the sensorium through the sense of vision. The sleep thus induced, however, is usually characterised by certain peculiarities which will be described hereafter.—The recurrence of impressions received through the sense of touch has the same effect. Thus Dr. Elliotson says*,—"I know a lady who often remains awake in spite of every thing, till her husband very gently rubs her foot; and by asserting to a patient my conviction that the secret of an advertising *hypnologist* whom I allowed to try his art upon the sleepless individual, and which he did for a time successfully, was to make him gently rub some part of his body till he slept, he confessed this to be the fact." The rocking of the infant's cradle, or the gentle swaying of the body backwards and forwards in the arms, are predisposing causes of sleep well known to nurses.

In these and similar cases, the influence of the impressions would seem to be exerted in withdrawing the mind from the consciousness of its own operations, the loss of which, as we shall presently point out, is the transition-step of the passage into complete unconsciousness. The reading of a dull book acts in the same mode. There is a monotony of sensorial impressions, the eyes wandering on from line to line and from page to page, without any mental interest in the sensations received; and if the voluntary effort of attention be intermitted, the thoughts pass off along their own spontaneous train, whilst the sensorial centres are left free to the soporific influence of monotony.

The foregoing are the chief causes of sleep, which operate directly through the sensorial organs themselves. We have now to consider those whose action is indirect, being exerted primarily on the organic functions. Of these the first in order of importance are those which produce increased *pressure* of blood within the vessels of the encephalon. Thus the assumption of the recumbent position operates in this method as a powerful predisponent to sleep, as well as by rendering all muscular effort unnecessary for the maintenance of the position of the body. To this cause again we are probably to attribute, in great part at least, the drowsiness which succeeds a full meal, the pressure within the encephalic vessels being increased by the pressure of the distended stomach upon the vessels of the abdomen; but the circulation of imperfectly assimilated matter in the blood may possibly concur in the production of the result. The influence of pressure is most characteristically seen in cases of gradual effusion of blood or of serum from the vessels of the brain; this at first occasions a state of sopor but little different from profound ordinary sleep; but with the increase of the effusion there is an increase in the depth of the slumber; the patient can no longer be aroused by sensorial impressions which were at first sufficient to re-excite consciousness, and at last complete coma comes on.† A

* Physiology, p. 609.

† Dr. Marshall Hall has advanced the hypothesis, that *ordinary sleep* is the result of congestion of the brain produced by compression of "certain veins,"

moderate degree of warmth favours sleep; perhaps by increasing the energy of the heart's contractions, at the same time that the walls of the vessels are more relaxed than usual, and thus yield to the impulse. A moderate degree of cold usually has the opposite effect, more especially when the cold is sufficient to produce uneasy sensations. But cold of great severity produces drowsiness, sopor, and even complete coma; apparently by producing a contracted state of the superficial vessels of the body, and thus occasioning an increase of sanguineous pressure on the encephalic centres. Again, the circulation of blood charged with narcotic substances through the brain, is one of the most powerful of all hypnotising agencies; and this, again, may produce every gradation of effect, between simple sleep, from which the patient may be easily aroused, and the profoundest coma. One of the most common instances of the operation of this cause, is the production of drowsiness by a deficiency of ventilation; the carbonic acid which accumulates in the blood, when not freely carried off in the air, having the properties of a powerful narcotic.

Phenomena of ordinary Sleep.—The state of perfect sleep is characterised by negative rather than by positive phenomena. As already stated, it essentially consists in the complete suspension of the sensorial powers, and of all those movements in which the nervous system participates, except the simply reflex: with this is conjoined a partial or complete suspension of the functional activity of the cerebrum. According to the more or less potent operation of the soporific causes, will be the degree of insensibility to impressions upon the afferent nerves. No ordinary cause, as we have already shown, is so powerful as previous fatigue. Of the profoundness of the sleep which may result from it,—in combination, perhaps, with two other agents, warmth, and an atmosphere somewhat charged with carbonic acid,—the following remarkable example may be cited from the "Journal of a Naturalist." It may be proper to mention that, the correctness of the statement having been called in question, it was fully confirmed by Mr. Richard Smith, the late senior surgeon of the Bristol Infirmary, under whose care the sufferer had been. "A travelling man, one winter's evening, laid himself down upon the platform of a lime-kiln, placing his feet, probably numbed with cold, upon the heap of stones, newly put on to burn through the night. Sleep overcame him in this situation; the fire gradually rising and increasing, until it ignited the stones upon which his feet were placed. Lulled by the warmth, the man slept on; the fire increased until it burned one foot (which probably was extended over a vent-hole) and part of the leg above the ancle entirely off, consuming that part so effectually, that a cinder-like fragment was alone remaining,—and still the wretch slept on! and in this state was found by the kiln-man in the morning. Insensible to any pain, and ignorant of his misfortune, he attempted to rise and pursue his journey, but missing his shoe requested to have it found; and when he was raised, putting his burnt limb to the ground to support his body, the extremity of his tibia crumbled into fragments, having been calcined into lime. Still he expressed no sense of pain, and probably experienced none, from the gradual operation of the fire, and his own torpidity during the hours his foot was consuming. This poor drover survived his misfortunes in the hospital about a fortnight; but the fire having extended to other parts of his body, recovery was hopeless." It may be added that cases are recorded by medico-legal writers, in which defloration of a virgin, followed by conception, has been effected whilst she was in a state of ordinary sleep, rendered unusually profound by previous fatigue; but such statements are obviously liable to considerable doubt, and scarcely appear entitled to credence.

Besides the suspension of the sensorial functions, however, there is usually a slight diminution in the activity of the functions of organic life. The heart's contractions are less frequent, but the pulse is fuller. So likewise the respiratory movements are diminished in number; but the inspirations are deeper. Less carbonic acid is produced than during a similar bodily inactivity in the waking state. As might be expected from these differences, the amount of heat generated in the body is diminished, and there is much less power of resisting the effects of cold. So remarkable is this abatement, that when the body is exposed to intense cold (as in the well-known attempt of Sir Joseph Banks and Dr. Solander to explore Terra del Fuego), "to sleep is to die." There would seem, too, to be a diminution in the power of resisting other morbific agencies. Thus all authorities agree that *sleeping* in a malarious atmosphere is much more liable to engender the diseases produced by it, than spending the same length of time in the same place, but in the waking state. As a general rule, it would seem that the secreting processes go on with diminished activity during sleep; but to this the cutaneous transpiration is an exception, so that, in debilitated states of the system, a profuse sweating often occurs as soon as the patient falls asleep. From this diminished activity of the organic functions it happens that hunger is not renewed so speedily after sleep as when the same number of hours have been passed in watching; a fact well known to those who are liable to suffer habitually or occasionally from the want of food. In this

by "a state of contraction of certain muscles of the neck." (See his Observations in Medicine, second series, p. 27.) He does not, however, offer the least proof of this hypothesis, nor does he even name the muscles or veins to which he refers. We presume that the platysma myoides and the external jugular are meant. If so, why should not a slight compression of the vein by any other means have the effect of producing sleep at will?

respect, then, even the ordinary sleep of the warm-blooded animal may be regarded as an incipient hybernation. Some writers have spoken of the organic functions as performed with *increased* activity during sleep; a doctrine so inconsistent with obvious facts, that it could never have been sustained except on the basis of a preconceived idea with regard to the antagonism between the relative activity of the functions of organic and animal life, which idea is in itself fallacious. The actual renovation of the nervous and muscular tissues by the nutritive processes, probably takes place with peculiar energy during the functional inactivity of those parts; but the preparation of the nutritive materials, which is the office of the digestive and assimilative apparatus, seems to go on more slowly during sleep; and it is quite certain that less oxygen is then taken into the system, and less carbonic acid generated and set free.

The *access* of sleep is sometimes quite sudden; the individual passing at once from a state of mental activity to one of complete torpor. More generally, however, it is gradual; and is marked by phenomena which are particularly worthy of attention. "While the mind remains poised, as it were, between sleep and the opposite condition," says Dr. Macnish*, "it is pervaded by a strange confusion, which almost amounts to wild delirium; the ideas dissolve their connection from it, one by one; those which remain longest behind are faint, visionary, and indistinct; and its own essence becomes so vague and diluted, that it melts away in the nothingness of slumber; as the morning vapours are blended with the surrounding air by the solar heat." In this passage there is an attempt made to depict the result of the loss of that power of voluntary control over the current of thought, the possession of which is the especial characteristic of the human mind in its state of normal activity. It is the complete suspension of this power, as we shall presently see, which, taken in connection with the entire want of sensibility to external objects, constitutes the state of dreaming; and the same suspension, occurring before the mind is altogether withdrawn from connection with the external world, constitutes that curious intermediate state betwixt sleeping and waking, which may readily pass into either condition. Thus, if the torpor of the sensorial centres be allowed to increase, sleep is produced; but if it be dissipated by some sensory impression of unusual strength, wakefulness is brought back again, a dreamy impression remaining, both of what had been passing in the mind itself, and of that which had been taking place around. Now, it appears to be by suspending the mind's attention to its own proceedings, and by drawing off the attention of the sensorium from all other impressions upon the organs of sense, that the monotonous sensations already referred to favour the access of sleep. And it may be further affirmed that all the successful plans for voluntarily producing sleep have some such *modus operandi;* their success being dependent upon the intentional fixation of the thoughts upon some one class of sensory impressions (as in the method of Mr. Gardner), or upon some very simple and uniform mental process (such as counting, repeating a French or Greek verb, &c.); and when the attention has been once thus fixed, the monotony of the impression serves to retain it there, so that it abandons, as it were, all control over its operations, and allows itself to be gradually wrapped in repose under the influence of that continued recurrence of similar impressions, which seems even more potent as a soporific than the suspension of *all* sensational stimuli.

The gradual loss of consciousness and of voluntary control over the muscular system during the invasion of sleep is thus described by Dr. Macnish: — "Previous to the accession of sleep, a feeling of universal lassitude prevails; this sensation heralds in the phenomena of slumber, and exhibits itself in yawning, heaviness of the eyes, indifference to surrounding objects, and all the characteristics of fatigue. If the person be seated, his head nods and droops, and, in all cases, the muscles become relaxed, and the limbs thrown into that state most favourable for complete muscular inaction. The lying position is, consequently, the best adapted for sleep, and the one which is intuitively adopted for the purpose. The organs of the senses do not relapse into simultaneous repose, but suspend their respective functions gradually and successively; sight, taste, smell, hearing, and touch, parting with sensation in the order in which they here stand, and gliding insensibly away. In the same manner the muscles do not become simultaneously relaxed; those of the limbs giving way first, then those of the neck, and lastly the muscles of the spine. Nor do the external senses, on awaking, recover all at once their usual vigour; we, for some seconds, neither hear, nor see, nor smell, nor taste, nor touch, with our usual acuteness. Ordinary sights dazzle our eyes; ordinary sounds confuse our ears; ordinary odours, tastes, and sensations, our nose, our tongue, and our touch: they awake successively, one after another, and not in the same instant." *

The power of being *aroused* by impressions made upon the organs of sense, is, as already remarked, one of the chief distinctions between *sleep* and *stupor*. The strength of the impression requisite to produce this effect depends upon two circumstances, which require separate consideration: first, the profoundness of the slumber; and, second, the relation of the impression to the habitual condition of the mind. It is a familiar fact that most persons are much more easily aroused towards the morning, when the slumbers are lighter, than they are during the early part of the night, when the sleep is more profound. In fact, the spontaneous awakening which takes place when our repose has been sufficient for the restoration of mental

* Philosophy of Sleep, p. 21.

* Op. cit. p. 22.

vigour, may generally be traced to some sensory impression of a trivial nature, such as the striking of a clock, which would have produced no effect at a previous time. Some persons, however, always sleep so heavily, that they require a strong impression to arouse them, even when they have had an ample allowance of repose. It is through the hearing and the touch that the awakening impressions are ordinarily conveyed; but either of the other senses may serve as their channel. Thus, although the closure of the eyelids destroys the acuteness of the perception of light, the eyelids are sufficiently transparent to allow of an impression being made by a light of moderate intensity; so that those who sleep in a room whose window has an eastern aspect, and is not furnished with sufficient means of excluding the sun's rays, are liable to be aroused by their ingress some time before the natural amount of repose has been taken. So, again, the sleeper may be awakened by unusual odours; thus the inmates of a burning house are sometimes first aroused by the smell of fire. The introduction of substances possessing a strong taste into the mouth, will also usually put an end to the state of slumber; but when the slumber is very profound, such substances may be received, and even swallowed, without the sleeper being thereby awakened.

The variety of modes in which the operation of sensory impressions on the sleeper is modified by the previous habitual state of mind, is one of the most remarkable points of the whole subject. The general rule is, that habitual impressions of any kind have much less effect in arousing the slumberer, than those of a new or unaccustomed character. An amusing instance of this kind has been related to the author, which, even if not literally true, serves extremely well as an illustration of what is unquestionably the ordinary fact. A gentleman who had taken his passage on board a ship of war, was aroused on the first morning by the report of the morning gun, which chanced to be fired just above his berth; the shock was so violent, as to cause him to jump out of bed. On the second morning he was again awoke, but this time he merely started and sat up in bed; on the third morning the report had simply the effect of causing him to open his eyes for a moment, and turn in his bed: on the fourth morning it ceased to affect him at all, and his slumbers continued to be undisturbed by the report as long as he remained on board. It often happens that sleep is terminated by the *cessation* of an accustomed sound, especially if this be one whose monotony or continuous repetition had been the original inducement to repose. Thus, a person who has been read or preached to sleep, will awake, if his slumber be not very profound, on the cessation of the voice; and a naval officer, sleeping beneath the measured tread of the watch on deck, will awake if that tread be suspended. In this latter case, the influence of the simple cessation of the impression will be augmented by the circumstance next to be alluded to, which has received too little attention from writers on this subject, but which is of peculiar interest both in a physiological and psychological point of view, and is practically familiar to almost every one.

This is, that the influence of sensory impressions is greatly modified by our habitual state of mind in regard to them. Thus, if we are accustomed to *attend* to these impressions, and our perception of them is thus *increased* in acuteness, we are much more easily aroused by them than by others which are in themselves much stronger, but of which we have been accustomed to entertain an utter disregard. Thus, most sleepers are aroused by the sound of their own names uttered in a low tone, when it requires a much louder sound of a different description to produce any manifestation of consciousness. The same thing is seen in comatose states; a patient being often capable of being momentarily aroused by shouting his name into his ear, when no other sound produces the least effect. The following circumstance, communicated to the author by a naval officer of high rank, is a most apposite illustration of this principle. When a young man, he was serving as signal-lieutenant under Lord Hood, at the time when the French fleet was confined in Toulon harbour; and being desirous of obtaining the favourable notice of his commander, he devoted himself to his duty — that of watching for signals made by the look-out frigates — with the greatest energy and perseverance, often remaining on deck nineteen hours out of the twenty-four, with his attention constantly directed towards this one object. During the few hours which he spent in repose, his sleep was so profound, that no noise of an ordinary kind, however loud, would awake him; and it used to be a favourite amusement with his comrades, to try various experiments devised to test the soundness of his sleep. But if the word "signal" was even whispered in his ear, he was instantly aroused, and fit for immediate duty.

It is not requisite, however, that the sound should be one habitually attended to during the hours of watchfulness; for it is sufficient if it be one on which the attention has been fixed as that at which the slumberer is to arouse himself. Thus the medical man, even in his first profound sleep after a fatiguing day's work, is aroused by the first stroke of the clapper of his night-bell; and to those who are accustomed to rise every morning at the sound of an alarum-clock, the frequency and regularity of the occurrence do not diminish, but rather increase, the readiness with which it produces its effect, provided that the warning be promptly obeyed. On this usually depends the efficiency of the awakening sound; if it be disregarded as a thing to which there is no occasion to give heed, it very soon ceases to produce any effect, the entire peal not being sufficient to awake the sleeper; whilst, on the other

hand, the first stroke is enough to break the repose of him who is impressed with the effectual desire of profiting by the warning. And thus it may happen that, of two persons in the same room, either shall be at once aroused by a sound which produces no disturbance in the slumbers of the other.— The influence of habitual attention is shown as much in the effect produced by the cessation, as in that of the occurrence, of sensory impressions. Thus in the case of the naval officer aroused by the suspension of the measured tread of the watch over his head, the knowledge possessed during the waking state that this suspension is either an act of negligence which requires notice, or indicates some unusual occurrence, doubtless augments the effect which the discontinuance of the sound would of itself produce.

Putting aside the awakening influence of external impressions, the period of natural termination of the slumber is greatly influenced by habit. Thus, many persons who are accustomed to rise at a particular hour, wake regularly at that hour, whether they have gone to rest early or late ; so that the act of spontaneously awakening is no proof that the desirable amount of repose has been obtained. But what is more remarkable is, that many individuals have the power of determining, at the time of going to rest, the hour at which they shall rise, so as to awake from a profound sleep at the precise time fixed upon. In others, however, the desire to rise at a particular hour only induces a state of restlessness throughout the night, destroying the soundness of the slumbers : the individual awakes many times in the night, with the belief that the hour is past, and very possibly oversleeps it after all, the system being worn out by the need of repose.

The *Amount of sleep* required by man is affected by many conditions, especially *age*, *temperament*, *habit*, and *previous exhaustion;* so that no general rule can be laid down upon the subject. The condition of the fœtus in utero may be regarded as one of continual slumber ; the energy of the organic functions being entirely directed to the building-up of the organism, whilst the apparatus of animal life is completely secluded from all the stimuli which could arouse it into activity. On its first entrance into the world, the infant continues to pass the greater part of its time in slumber; and this is particularly to be noticed in cases of premature birth,—the seven months' child seeming to awake only for the purpose of receiving food, and giving but little heed to any external objects when its internal cravings are satisfied; and even the eight months' infant being considerably less alive to sensory impressions, than one born at the full time. During the whole period of infancy and childhood, it is necessary for the development of the body that the *constructive* operations should be more energetic than the *destructive;* and, accordingly, we find that the period of sleep, during which the former take place without hindrance, is longer in proportion to the waking state, during which the latter are in play, than it is when full growth has been obtained.*

As age advances, the necessity for very rapid nutrition gradually diminishes, in consequence of the progressive approach to complete development ; and when the adult period has been attained, it is not requisite that the *constructive* processes should do more than balance the *destructive*. The amount of sleep requisite for this purpose, therefore, gradually diminishes, until it is reduced to (at most) one-third of the cycle of twenty-four hours. It is to be noticed that the sleep of children and young persons is not only longer than that of adults, but is also more profound. On the other hand, as age advances, and the bodily and mental activity of the waking state decreases, a smaller amount of sleep suffices ; or, if the slumber be protracted, it is usually less deep and refreshing. It may be noticed, however, that *very* old persons usually pass a large proportion of their time in sleep, or rather in dozing ; as if, in consequence of the want of energy of their nutritive operations, a very long period of repose is necessary to repair the waste which takes place during their short period of activity. It is stated† that " the celebrated De Moivre slept twenty hours out of the twenty-four ; and Thomas Parr latterly slept away by far the greater part of his existence." The repose of the aged is most apt to take place immediately after taking food ; while they solicit it in vain at that period at which, during the former years of their lives, they had been accustomed to enjoy it.

The amount of sleep, again, is much affected by *temperament*. It will generally be found that a plethoric habit of body, sustained by full diet, predisposes to sleep, provided the digestive powers be in a vigorous condition. Such persons frequently pass nine or ten hours in slumber, and maintain that they cannot be adequately refreshed by less. On the other hand, thin wiry people, in whom the " nervous" temperament predominates, usually take comparatively little sleep, notwithstanding the greater activity of their nervous system when they are awake ; but their slumber, while it lasts, is generally very deep. Persons of " lymphatic" temperament, heavy

* It is to be remembered, when we compare the condition of the nutritive operations during the period of growth, and after the complete development of the organism, that it is not in the mere amount of *accretion* that the difference consists. This would be the case if the new matter were merely *added* to the old, as in the formation of a new layer of wood in an exogenous stem. The growth of the animal fabric requires a continual new development of every part of it, involving a constant change in its materials ; and thus we see that the amount of food required by children, and the quantity of urea, and other products of the disintegration of the tissues set free in their excretions, bear a much larger proportion to those of the adult, than would be inferred from the relative bulk of the body at the two periods, and from its rate of increase during the former.

† Macnish, op. cit. p. 37.

passionless people, who may be said to live very slowly, are usually great sleepers; but this rather because, through the dullness of their perceptions, they are less easily kept awake by sensorial or mental excitement, than because they really require a prolonged cessation of activity. As they are half asleep during the waking state, so would it appear that the constructive operations must be far from active while they are asleep,—so little do they seem restored by the repose.

The amount of sleep, *cæteris paribus*, required by individuals, is very greatly influenced by *habit;* and, contrary to what we might anticipate, we find that the briefest sleepers have usually been men of the greatest mental activity. Thus Frederick the Great and John Hunter are said to have only required five hours' sleep out of the twenty-four. General Elliot, celebrated for his defence of Gibraltar, is recorded not to have slept more than four hours out of the twenty-four.* Sir Gilbert Blane states† that General Pichegru informed him that, " in the course of his active campaigns, he had for a whole year not more than one hour of sleep, on an average, in twenty-four hours." We suspect that if he had said "one hour of sleep at a time," he would have been nearer the truth. This we believe to have been the case with regard to the Duke of Wellington during the Peninsular campaigns. Dr. Elliotson says‡, " I heard Baxter, the coachmaker, declare that he never took more than three hours' sleep during the most active period of his life." We doubt if it would be possible for any one to sustain a life of vigorous exertion with a smaller allowance than this.

The influence of habit is further shown in producing an aptitude for repose, or a readiness to wake, at particular periods. Thus, if a man is accustomed to go to rest at ten o'clock, and to rise at six, he will probably awake at six, even if he have not fallen asleep until twelve. And in like manner, if the morning sleep have been unusually protracted, the desire for sleep will probably return at the accustomed hour in the evening. The influence of habit is further exerted in producing an aptitude for sleep whenever the opportunity is afforded. Thus, the celebrated pedestrian Capt. Barclay, when accomplishing his extraordinary feat of walking 1000 miles in as many successive hours, obtained at last such a mastery over himself that he fell asleep the instant he lay down. And the sleep of soldiers, sailors, and others, who may be prevented from obtaining regular periods of repose, but are obliged to take their rest at short intervals, may be almost said to come at command; nothing more being necessary to induce it than the placing the body in an easy position, and the closure of the eyes. On the other hand, habit favors the protraction of sleep. This was the case with Quin, the celebrated actor, who could slumber for twenty-four hours successively; and with Dr. Reid, the metaphysician, who could take as much food, and afterwards as much sleep, as were sufficient for two days.

* Macnish, op. cit. p. 34.
† Medical Logic, p. 83.
‡ Physiology, p. 601.

It is needless to dwell upon the obvious fact, that, other things being equal, the amount of sleep required by man is proportional to the amount of mental exertion put forth during the waking hours; since this is an obvious result of what has been laid down as the cause of the demand for sleep. It may be remarked, however, that we must not measure the *amount* of sleep by its *duration* alone; since its *intensity* is a matter of equal importance. The light slumber which is disturbed by the slightest sounds, cannot be as renovating as the profound sopor of those whom no ordinary noise will awake.

There are certain states of the nervous system in which there is an *entire absence of sleep;* and this may continue for many days, or even weeks or months. Insomnia is, for instance, one of the characteristics of acute mania, and may also exist in various forms of monomania. It is usually, also, one of the symptoms of incipient meningeal inflammation. And it may constitute a specific disease in itself. In all these cases, however, the preponderance of the *destructive* processes over the *constructive* manifests itself, sooner or later, in the exhaustion of the mental and bodily powers. Thus mania, when prolonged or frequently occurring, subsides into dementia. When meningitis (or rather inflammation of the surface of the hemispheric ganglia) is fully developed, a rapid disintegration of nervous matter takes place, as indicated by the large amount of alkaline phosphates in the urine.* The same would probably be detected in cases of idiopathic insomnia; which state, if it continue for any length of time, is sure to be followed by a great sense of wretchedness and prostration, frequently accompanied by continual restlessness. Such effects, too, in a less aggravated degree, result from habitual *deficiency* of sleep; whether this results from emotional excitement, which keeps repose at bay, or from a voluntary determination to keep the intellect in activity. This is a very common occurrence among industrious students, who, with a laudable desire for distinction, allow themselves less than the needed quantum of repose. Headache, tension, heat, throbbing, and various other unpleasant sensations in the head, give warning that the brain is being overtasked; and if this warning be not taken, sleep, which it was at first difficult to resist, becomes even more difficult to obtain; a state of general restlessness and feverish excitement are induced; and if, in spite of this, the effort be continued, serious consequences, in the form of cerebral inflammation, apoplexy, paralysis, fever, insanity, or loss of mental power, more or less complete, are nearly certain to be induced. Some individuals can sustain such an effort much longer than others, but it is a great mistake to suppose that they are not

* See Dr. Bence Jones in Phil. Trans. 1846.

equally injured by it; in fact, being possessed with the belief that they are not suffering from the exertion, they frequently protract it until a sudden and complete prostration gives a fearful demonstration of the cumulative effects of the injurious course in which they have been persevering. Those, consequently, who are earlier forced to give way, are frequently capable of accomplishing more in the end.

In regard to the degree of *protraction* of sleep which is consistent with a healthy state of the system in other respects, it is difficult to speak with certainty. Of the numerous well-authenticated instances on record *, in which sleep has been continuously prolonged for many days or even weeks, it is enough here to state that they cannot be regarded as examples of natural sleep; the state of such persons being more closely allied to hysteric coma. An unusual tendency to proper sleep generally indicates a congested state of the brain, tending to apoplexy; and it has been stated that apoplexy has been actually induced by the experimental attempts to ascertain how large a proportion of the diurnal cycle might be spent in sleep. This effect may be readily explained, if we regard it as a general law of the capillary circulation, that its rate is increased by functional activity, and diminished by inactivity; for whilst congestion of the brain arising from other causes will tend to produce sleep, through the augmented pressure it occasions, mental inactivity, if encouraged and persisted in, will itself tend to produce congestion.

Thus, on either side, inattention to the dictates of Nature in respect to the amount of sleep required for the renovation of the system, becomes a source of disease, and should therefore be carefully avoided.

DREAMING.

We have hitherto spoken of sleep in its most complete or profound form, — that is, the state of complete unconsciousness. But with the absence of consciousness of external things, there may be a state of mental activity, of which we are more or less distinctly conscious at the time, and of which our subsequent remembrance in the waking state also varies in completeness: the impression being sometimes vivid, definite, and enduring; sometimes shadowy and evanescent; sometimes not amounting to more than the feeling that we have dreamed; and sometimes not even this being preserved, notwithstanding that there may be positive assurance that the sleep has been thus disturbed. This state, known as *dreaming*, is one of the highest interest to the psychologist; but the limits imposed upon us forbid our doing more than enumerate its leading phenomena.

The chief feature of the state of dreaming appears to be, that there is an entire *absence of voluntary control* over the current of thought; so that the principle of *suggestion*—one thought calling up another, according to the laws of association—has unlimited operation. Sometimes the train of thought thus carried on is remarkably consistent. We witness scenes that have occurred during our waking hours, and seem to hear, see, move, talk, and perform all the actions of life. We may experience every kind of mental emotion, and may even compare, reason, judge, and will, during our sleep; and our reasoning processes have frequently a remarkable clearness and completeness, — the data on which they are founded being supposed to be accurate. This consistency is usually the greatest, when the mind simply takes up a train of thought on which it had been engaged during the waking hours, not long previously; and it may even happen that, in consequence of the freedom from distraction occasioned by the suspension of ordinary sensations, the intellectual operations may be carried on during sleep with uncommon vigour and success. Thus, to name only two instances, Condorcet saw, in his dreams, the final steps of a difficult calculation, which had puzzled him during the day; and Condillac states that, when engaged with his "Cours d'Etude," he frequently developed and finished a subject in his dreams, which he had broken off before retiring to rest.

The imagination, equally with the reasoning processes, sometimes moves in a consistent course. Thus, Dr. Good relates the case of a friend who composed a little ode of about six stanzas, and set the same to agreeable music, in his sleep, the impression remaining so vividly that he was able to write down both the words and music on awaking in the morning; and Coleridge relates of himself that his fragment, entitled "Kubla Khan," was composed during sleep, which had come upon him whilst reading the passage in "Purchas's Pilgrimage" on which the poetical description is founded, and was written down immediately on awaking. The images, he says, "rose up before him as things, with a parallel production of the correspondent expressions, without any sensation or consciousness of effort." It would seem necessary, in most cases of this kind, that the results should be committed to paper immediately on waking, before the train of thought, continued from the dream, has been disturbed by any other. Thus, Coleridge tells us that, after having written for some little time, he was interrupted by a person on business, who continued with him above an hour; and on the departure of his visitor, he found, to his surprise and mortification, that "though he still retained some vague and dim recollection of the general purport of the vision, yet, with the exception of some eight or ten scattered lines and images, all the rest had passed away like the images on the surface of a stream into which a stone had been cast; but, alas! without the after-restoration of the latter." In other cases, a strong general impression of what has passed through the mind in sleep may remain on waking, without power of recalling the particulars. This was the case in the well-known instance of the musician Tartini, to whom the

* Such, for example, as that of Samuel Chilton (Phil. Trans., 1694), and that of Mary Lyall (Trans. of Roy. Soc. of Edinb., 1818).

arch-fiend appeared in his sleep, and was challenged by him to a trial of skill: the dreamer lay entranced by the transcendent performance of his visitor, which surpassed anything he had ever heard or conceived; on awaking, however, he could not reproduce the succession of notes, although he immediately seized his violin, and endeavoured to do so; but, under the strong general impression of what he had heard, he produced a new composition, which retains the name of the "Devil's Sonata."

But, although dreams *may* possess a remarkable coherence, whether as regards processses of reasoning, or the new combinations of the imagination, the general fact is, that such coherence is altogether wanting, and that there is a complete incongruousness in the thoughts and images which pass through our minds. All probabilities, and even possibilities of "time, place, and circumstance" are violated; the dead pass before us as if alive and well; even the sages of antiquity hold personal converse with us; our friends at the antipodes are brought upon the scene, or we ourselves are conveyed thither, without the least perception of distance; and the strangest combinations of reality and fancy are presented, either as objects passing before our consciousness, or as affecting our own condition. But of this incongruity we are seldom in the least aware. We are not capable of testing the probability or possibility of the phenomena by our ordinary experience. And, as a consequence of this, nothing surprises us in dreams; the feeling of surprise being the result, and indeed the measure, of our perception of the unlikelihood of a phenomenon. Not only is there usually a want of congruity in the intellectual processes, but a great disturbance in the ordinary play of the emotions. "Thus, in our dreams we may walk on the brink of a precipice, or see ourselves doomed to immediate destruction by the weapon of a foe or the fury of a tempestuous sea, and yet feel not the slightest emotion of fear; though, during the perfect activity of the brain, we may be naturally disposed to the strong manifestation of this feeling. Again, we may see the most extraordinary object or event without surprise, perform the most ruthless crime without compunction, and see what in our waking hours would cause us unmitigated grief, without the smallest feeling of sorrow."* This is, however, by no means uniformly the case. In fact, our emotions in the dreaming state are often highly wrought; and it frequently seems that the excitement of some particular emotion gives the direction to the whole train of thought, and causes it to possess an unusual coherence and probability. This is most remarkable, perhaps, when the emotion in question has greatly occupied the mind in the previous waking hours. Thus, a female, whose husband is at sea, and for whose safety she naturally feels anxious, especially in stormy weather, is very apt to dream of shipwreck and all its attendant circumstances; or, on the other hand, a man in love dreams of his mistress, of married life, and of its various enjoyments. Even here, however, the congruity is frequently interrupted by the intervention of some strange occurrence; the oddity of which may be perceived by the dreamer as being discordant, not with the intellectual but with the emotional state.

* Prof. Wheatstone, quoted in Elliotson's Physiology, p. 621.

In simple dreaming, as there is a loss of voluntary control over the current of thought, so is there an absence of control over the muscular system. Movements expressive of emotions, however, may still take place, and may afford to the by-stander an indication of what is passing in the mind of the dreamer. The indications of fear, horror, or disgust, or of hope, rapture, or desire,—laughter or weeping, smiles or frowns,—may all display themselves, when there is an absolute cessation of all voluntary movements. This is remarkably the case in attacks of *incubus*, or nightmare; in which the dreamer is oppressed by intolerable distress, from which he makes vain attempts to free himself. His distress may be expressed by moans, or by the agitation of his countenance; but none of his fancied efforts are indicated by any respondent movements. This condition may subside into a state of tranquil slumber, or the agitation may increase to such a pitch as to awake the sufferer; and as the first act of the waking state is usually to cry out or kick violently, it has been supposed that the return of volition has been the cause, instead of being the effect, of the cessation of the oppressive dream. There are cases, however, in which the dreamer executes movements in consonance with *ideas* passing through his mind,—such as would, in the waking state, be termed voluntary; but these must be considered as belonging rather to the category of somnambulism than to that of simple dreaming.

The direction of the current of thought in dreaming is often given by impressions on the organs of sense, which influence the mental operations, by calling up associated ideas, without being recognized and perceived as distinct sensations. Thus, Dr. James Gregory, having applied a hot bottle to his feet on going to bed, dreamt that he was walking up Etna and finding the ground intolerably hot. On another occasion, he dreamt of spending a winter at Hudson's Bay, and of suffering much distress from the intense frost; this evidently the consequence of his having thrown off the bed-clothes in his sleep, and of his having been reading, a few days before, a very particular account of the state of the colonies in that country during winter. Dr. Reid, having a badly-dressed blister on his head, dreamt that he was being scalped by Indians; and a man in a damp bed, that he was being dragged through a stream. A gouty man, when beginning to feel his pain in his sleep, may dream he is on the rack before inquisitors. The sound of music may excite delightful dreams. M. Girou de Buzareingues* made some curious experiments on

* Journal de Physiologie, tom. viii.

this point, and directed at pleasure the character of his dreams. In his first experiment, having allowed the back of his head to be uncovered during sleep, he thought he was at a religious ceremony in the open air; the custom of the country in which he lived being to keep the head covered excepting on some rare occurrences, among which was the performance of religious ceremonies. On waking he felt cold at the back of the neck, as he frequently had when present at the real ceremonies. He repeated the experiment in two days, with the same result. In a third experiment, he left his knees uncovered, and dreamt that he was travelling at night in the diligence; and all travellers know, he observes, that it is chiefly at the knees that they feel cold when travelling by that conveyance at night. The very remarkable degree in which this influence of external impressions is exerted, when sleep is being induced by the agency of certain narcotics, will be presently noticed. By the use of the term "external" is here meant that which is external to the mind itself. The dream may originate in impressions derived from any part of the bodily frame. Thus we find that indigestion is a very common cause of nightmare, and that an irritable state of the genital apparatus provokes lascivious dreams. When the external impressions are recognized as *sensations*, and the dreamer's current of thought completely follows their guidance, so that even the meaning of spoken language is appreciated, the condition approximates to that of Somnambulism.

One of the most remarkable of all the peculiarities of the state of dreaming, is the rapidity with which trains of thought pass through the mind; a dream in which a long series of events has seemed to occur, and a multitude of images has been successively raised up, being often certainly known to have occupied but a few minutes or even seconds. This is best seen in those cases in which the dream has obviously originated in some sensory impression, which has also had the effect of arousing the sleeper. A very interesting example of this, in which a similar dream was produced in two individuals, husband and wife, from the same cause, came within the knowledge of the late Dr. James Gregory. It happened when the public mind was much excited in regard to the alarm of French invasion, and the gentleman who was the subject of it was himself a zealous member of the Edinburgh volunteer corps. Whilst asleep, between two and three o'clock in the morning, he dreamt of hearing the signal gun: he was immediately at the Castle, witnessed the proceedings for displaying the signals to alarm the country, and saw and heard a great bustle over the town, from troops and artillery assembling, especially in Princes Street. At this time he was roused by his wife, who awoke in a fright, in consequence of a similar dream, connected with much noise and the landing of the enemy, and concluding with the death of a particular friend of her husband's, who had served with him as a volunteer. The origin of this remarkable occurrence was ascertained, in the morning, to be the noise produced in the room above by the fall of a pair of tongs. How long the dream had continued in this instance is uncertain; evidently not for a period in the least comparable to that required for the actual occurrence of the events that had passed through the mind of each; and it is probable, from many similar cases, that the lady was awoke by the noise rather than by the fright. Thus a gentleman dreamt that he had enlisted as a soldier, joined his regiment, deserted, was apprehended, carried back, tried, condemned to be shot, and at last led out for execution. After all the usual preparations, a gun was fired; he awoke with the report, and found that a noise in an adjoining room had both produced the dream and awoke him. The same feeling of duration, arising out of the number of images passing in succession through the mind, is often experienced when we are well assured that the whole duration of our sleep has not exceeded a few moments. We have known a clergyman fall asleep in his pulpit during the singing of the psalm before sermon, and awake with the conviction that he must have slept for at least an hour, and that the congregation must have been waiting for him; but on referring to his psalm-book, he has been consoled by finding that his slumber has lasted no longer than during the singing of a single line. There would not seem, in fact, to be any limit to the amount of thought which may thus pass through the mind of the dreamer, in an interval so brief as to be scarcely capable of measurement; and this view is confirmed by the circumstance, now well attested, that it is a common occurrence in drowning for the whole previous life of the individual to be presented instantaneously to his view; with its every important incident vividly impressed on his consciousness, just as if all were combined in a picture, every part of which could be taken in at a glance. This, again, is connected with the fact that the operation of the associative principle may reproduce in dreams the remembrance of facts long since forgotten in the waking state. Such, however, is by no means peculiar to the state of dreaming; for in the waking state we often retrace involuntarily and unexpectedly something which we have in vain attempted to recall at will, and which might be said to have passed from our mental grasp.

From the foregoing and other similar facts it has been argued, that *all* our dreams really take place in the act of falling asleep or of awaking; so that even when we fancy that we have been dreaming all night, our unconsciousness has been really complete, except at these momentary intervals. That this doctrine cannot be altogether true is obvious from the fact, that we can frequently detect the character of a dream, and even in some degree trace its progress, by the expression of the sleeper's countenance; so that dreams certainly *may* occupy time, and occur during

ordinary sleep. On the other hand, it may be freely admitted that the apparent duration of our dreams does not afford the least measure of the time they have really occupied; and that it is probable that even when our sleep has seemed most disturbed by them, we have really passed a larger portion of the night in a state of complete unconsciousness than the mere impression left by our dreams would allow us to believe. But it has been questioned by some, on the other hand, whether there is ever such a state as that of complete unconsciousness. It is affirmed that the mind *can never* be entirely inactive; and that every body, in fact, does dream throughout the period of sleep, although the dreams may not be remembered in the waking state. This statement is rather based upon the hypothesis with which it commences, than upon any positive facts; and as it requires us to give up the simple teachings of ordinary experience, for the reception of a mere metaphysical dogma, the physiologist need not concern himself with the discussion.

On the whole, it may be said that dreaming indicates that sleep is imperfect; and this view harmonises with the fact that between dreaming and the waking state there are various connecting gradations. Thus, reverie or day-dreaming differs from the dreaming of the sleeper, not so much in the condition of the mind and its instrument the cerebrum, as in that of the sensorium, which is not so completely withdrawn in the former case, as it is in the latter, from the consciousness of external impressions. In sleep, on the other hand, the dreamer may have a consciousness of the unreality of the images that arise in his mind, and may even make a voluntary and successful effort to prolong them if agreeable, or to dissipate them if unpleasing; thus evincing the presence of that power of control over the current of thought, the want of which is one of the best characteristics of ordinary dreaming, as it is also of insanity, and indicating, therefore, an unusual approximation to the vigilant condition.

The action of narcotics on the nervous system presents many curious illustrations of the foregoing statements regarding the nature and phenomena of dreaming. There are some which have the power of inducing every condition intermediate between an unusual activity of the thoughts and a state of complete stupor, according to the dose taken. This is the case to a certain degree with opium; but still more decidedly with the extract of *Cannabis Indica*, a preparation of whch, known under the names of Hachisch and Dawamesc, is much used in the East for the production of a species of agreeable intoxication. The first effect of a dose of this substance is usually to produce a moderate exhilaration of the feelings and an unusual activity of the intellectual powers; but this activity gradually frees itself from voluntary control. The individual feels himself incapable of fixing his attention upon any subject; his thoughts being continually drawn off by a succession of ideas which force themselves (as it were) into his mind, without his being able in the least to trace their origin. These speedily occupy his attention, and present themselves in strange combinations, so as to produce the most fantastic and impossible creations. By a strong effort of the will, however, the original thread of the ideas may still be recovered, and the interlopers driven away. These lucid intervals successively become of shorter duration, and can be less frequently procured by a voluntary effort; for the internal tempest becomes more and more violent, the torrent of disconnected ideas increases in power so as completely to arrest the attention, and the mind is gradually withdrawn altogether from the contemplation of external realities, being engrossed by the consciousness of its own internal workings. There is always preserved, however, a much greater amount of self-consciousness than exists in ordinary dreaming; the condition rather corresponding with that just referred to, in which the sleeper *knows* that he is dreaming. The succession of ideas has at first less of incoherence than in ordinary dreaming, the ideal events not departing so far from possible realities; and the disorder of the mind is at first manifested in errors of sense, in false convictions, or in the predominance of one or more extravagant ideas. These ideas and convictions are generally not altogether of an imaginary character, but are called up by external impressions, which are erroneously interpreted by the perceptive faculties. The error of perception is remarkably shown in regard to time and space; minutes seem hours, hours are prolonged into years, and at last all idea of time seems obliterated, and past and present are confounded together as in ordinary dreaming: and in like manner, streets appear of an interminable length, and the people at the other end seem to be at a vast distance. Still there is a certain consciousness of the deceptive nature of these illusions, which, if the dose be moderate, is never entirely lost.

The effect of a full dose, however, is at last to produce the complete withdrawal of the mind from any distinct comprehension of external things; the power of the will over the current of thought is in like manner suspended, and the condition of the mind becomes the same in all essential particulars with that of the ordinary dreamer; differing in this chiefly, that the feelings are more strongly exerted, and that they still take their tone almost entirely from external impressions. Thus, says M. Moreau*, "It will be entirely dependent on the circumstances in which we are placed, the objects which strike the eyes, the words which fall on our ears, whether the most lively sentiments of gaiety or of sadness shall be produced, or passions of the most opposite nature shall be excited, sometimes with extraordinary violence; for irritation

* Du Hachisch et de l'Aliénation Mentale, Etudes Psychologiques, p. 67.

shall pass rapidly into rage, dislike to hatred, and the desire of vengeance and the calmest affection to the most transporting passion. Fear becomes terror, courage is developed into rashness which nothing checks, and which seems not to be conscious of danger, and the most unfounded doubt or suspicion becomes a certainty. The mind has a tendency to exaggerate everything, and the slightest impulse carries it along. Those who make use of the hachisch in the East, when they wish to give themselves up to the intoxication of the *fantasia*, take great care to withdraw themselves from everything which could give to their delirium a tendency to melancholy, or excite in them anything else than feelings of pleasurable enjoyment. They profit by all the means which the dissolute manners of the East place at their disposal. It is in the midst of the harem, surrounded by their women, under the charm of music and of lascivious dances executed by the Almees, that they enjoy the intoxicating dawamesc; and with the aid of superstition, they find themselves almost transported to the scene of the numberless marvels which the Prophet has collected in his Paradise."*

SOMNAMBULISM.

Our history of sleep would be incomplete without some account of a state which is closely allied to it, though differing from it in several important particulars. The phenomena of somnambulism are so varied, that it is very difficult to frame any definition capable of including them all; and we prefer characterising the state by saying that it may be considered as an *acted dream*,—differing from ordinary dreaming in the two following points. In the first place, the train of thought is more under the direction of sensations derived from without; and, secondly, the muscular system is so completely under the control of the mind, as not merely to give expression to its emotional states, but also to act in respondence to its volitions. As in dreaming, there would seem to be, in true somnambulism, a complete want of voluntary control over the current of thought, but there is not the same degree of mental activity; and in particular the operation of the associative principle is so much more restricted, that there is little or none of that incoherence or incongruity in the ideas brought up, which is so peculiar in ordinary dreaming. On the contrary, reasoning processes are often carried out with extraordinary clearness and correctness; the mind being intently fixed upon them to the exclusion of all other considerations. This *exclusiveness*, indeed, is one of the most remarkable characteristics of the condition. Whilst the attention of the mind remains fixed upon any object, either perceived by the senses or brought up by the act of conception, nothing else is felt. Thus there may be complete insensibility to bodily pain, the somnambulist's whole attention being given to that which is passing within the mind. Yet, in an instant, by directing the attention to the organs of sense, the anæsthesia may be succeeded by the most acute sensibility. So, again, when the attention is fixed upon a certain train of thought, whatever is spoken in harmony with it is heard and appreciated by the somnambulist; but whatever is in discordance with it is entirely disregarded. The character of the intellectual operations partakes of this peculiarity. As just now stated, the reasoning processes are usually accurately and definitely carried on, so that the conclusion will be sound, provided that the data have been correct. Thus, a mathematician will work out a difficult problem, or an orator will make a speech appropriate to a given subject. But the usual defect of the intellectual operations carried on in this condition is, that, owing to their very intensity, the attention is drawn off from the considerations which ought to modify them; and thus it happens that the result is often palpably inconsistent with the teachings of ordinary experience, and will be admitted to be so by the somnambulist when the former are brought to his mind.

The state of somnambulism may pass, on the one hand, into that of ordinary dreaming, so that it is difficult to draw the line between the two. Thus, the ordinary "talking in the sleep" may be referred to one or the other condition, according to the definition of each that we may adopt. In our own arrangement, they fall under the second head: because the vocal movements are expressions of the intellectual processes that are taking place in the mind; and because, in most cases of this kind, the sleep-talker hears and comprehends what is said to him, provided that this harmonises with what is going on within, and will answer rationally, so as to sustain a conversation. Thus, we knew a young lady at school, who frequently began to talk after having been asleep an hour or two; her ideas almost always ran upon the events of the previous day; and if encouraged by leading questions addressed to her, she would give a very distinct and coherent account of them; frequently disclosing her own peccadilloes and those of her schoolfellows, and expressing great penitence for the former, whilst she seemed to hesitate about making known the latter. To all ordinary sounds, however, she seemed perfectly insensible. A loud noise would awake her, but

* The celebrated oriental scholar, M. Sylvestre de Sacy, appears to have made it pretty plain that our word *assassin* is derived from *Hachischin*, in the following manner. It is well known that the term was originally employed in Syria, to designate the followers of the "Old Man of the Mountain," who were accustomed to devote themselves with blind obedience to the execution of the orders of their chief, sacrificing themselves or others with equal readiness. Their education tended in every way to impress upon them this duty; and as a reward for its performance, they were promised after death all the sensual pleasures they could imagine,—a foretaste of these being every now and then given to them by intoxicating them with *hachisch*, in the midst of scenes in which everything was provided to gratify their senses. In this manner, a sort of fanaticism was gradually induced, which rendered them fit agents of the murderous designs of their master.

was never perceived in the sleep-talking state; and if the interlocutor addressed to her any questions or observations that did not fall in with her train of thought, they were completely disregarded. By a little adroitness, however, she might be led to talk upon almost any subject; a transition being gradually made from one to another by means of leading questions.

The well-known case of the officer, narrated by Dr. James Gregory, is one of the same intermediate class; rather allied, in our apprehension, to somnambulism than to ordinary dreaming. This gentleman, who served in the expedition to Louisburgh in 1758, was in the habit of *acting* his dreams; and their course could be completely directed by whispering into his ear, especially if this was done by a friend with whose voice he was familiar; so that his companions in the transport were in the constant habit of amusing themselves at his expense. At one time they conducted him through the whole progress of a quarrel, which ended in a duel; and when the parties were supposed to be met, a pistol was put into his hand, which he fired, and was awakened by the report. On another occasion they found him asleep on the top of a locker or bunker in the cabin, when they made him believe he had fallen overboard, and exhorted him to save himself by swimming. He immediately imitated all the motions of swimming. They then told him that a shark was pursuing him, and entreated him to dive for his life. He instantly did so, with such force as to throw himself entirely from the locker upon the cabin-floor, by which he was much bruised, and awakened of course. After the landing of the army at Louisburgh, his friends found him one day asleep in his tent, and evidently much annoyed by the cannonading. They then made him believe that he was engaged, when he expressed great fear, and showed an evident disposition to run away. Against this they remonstrated; but, at the same time, increased his fears, by imitating the groans of the wounded and the dying; and when he asked, as he often did, who was down, they named his particular friends. At last they told him that the man next himself in the line had fallen, when he instantly sprung from his bed, rushed out of the tent, and was roused from his danger and his dream together, by falling over the tent-ropes. After these experiments, he had no distinct recollection of his dreams, but only a confused feeling of oppression and fatigue; and used to tell his friends that he was sure they had been playing some trick upon him. This is another point of conformity with somnambulism; one of whose most distinctive peculiarities it is, that neither the trains of thought nor any of the events of the somnambulistic state are remembered in the ordinary waking condition, though the impression of the feelings strongly excited during that state, is sometimes continued. Both the trains of thought and the events of the somnambulistic state, however, are frequently remembered with the utmost vividness on the recurrence of that state, even at a very distant interval: and of the interval, however long it may have been, there is no consciousness whatever. The same thing, but more rarely, occurs in dreaming; the dreamer sometimes recollecting a previous dream, and even taking up and continuing its thread, although he could not in the least retrace it in his waking state.

A remarkable case of spontaneous somnambulism, which occurred within our own experience, will serve to illustrate many of the most characteristic features of the condition in question. The subject of it was a young lady of highly nervous temperament; and the affection occurred in the course of a long and trying illness, in which almost every form of hysteria, simulating tetanus, epilepsy, coma, and paralysis, had successively presented itself. Although natural somnambulism ordinarily arises out of ordinary sleep, yet in this instance the patient usually passed into the somnambulistic condition from the waking state; the transition being immediately manifested by the peculiar expression of the countenance. In this condition her ideas were at first entirely fixed upon one subject — the death of her only brother, which had occurred some years previously. To this brother she had been very strongly attached; she had nursed him in his last illness; and it was perhaps the return of the anniversary of his death about the time when the somnambulism first occurred, that gave to her thoughts that particular direction. She talked constantly of him, retraced all the circumstances of his illness, and was unconscious of anything that was said to her which had not direct reference to this subject. On one occasion she mistook her sister's husband for her lost brother; imagined that he was come from heaven to visit her; and kept up a long conversation with him under this impression. This conversation was perfectly rational on her side, allowance being made for the fundamental errors of her data. Thus, she begged her supposed brother to pray with her; and on his repeating the Lord's Prayer, she interrupted him after the sentence "forgive us our trespasses," with the remark, "But *you* need not pray thus; *your* sins are already forgiven." Although her eyes were open, she recognised no one in this state, not even her own sister, who, it should be mentioned, had not been at home at the time of her brother's illness.

On another occasion, it happened that, when she passed into this condition, her sister, who was present, was wearing a locket, containing some of their deceased brother's hair. As soon as she perceived this locket, she made a violent snatch at it, and would not be satisfied until she had got it into her own possession, when she began to talk to it in the most endearing and even extravagant terms. Her recognition of this locket, when she did not perceive that her sister was the wearer of it, was a very curious fact, which may be explained in two ways, each of them in accordance with the known laws of somnambulism. Either the concentration of her thoughts on this one subject caused her to remember only that which was

immediately connected with her brother; and her unconsciousness of the presence of her sister might be due to the absence of the latter at the time of his death, which caused her to be less connected with him in the thoughts of the somnambulist:—or it may have happened that she was directed to this locket by the sense of smell, which is frequently exalted in a very remarkable degree in the somnambulistic state. (See SMELL.) Her feelings were so strongly excited by the possession of the locket, that it was judged prudent to check their continuance; and as she was inaccessible to all entreaties on the subject, force was employed to obtain it from her. She was so determined, however, not to relinquish it, and was so angry at the gentle violence used, that it was found necessary to abandon the attempt; and she became calmer after a time, and at last passed off into ordinary sleep, which was in her case the successor, instead of being (as it usually is) the predecessor, of the somnambulistic state. Before going to sleep, however, she placed the locket under her pillow, remarking, "Now I have hid it safely, and they shall not take it from me." On awaking in the morning, she had not the slightest consciousness of what had passed; but the impression of the excited feelings remained; for she remarked to her sister,—"I cannot tell what it is that makes me feel so; but every time that S—— comes near me, I have a kind of shuddering sensation;"—the individual named being a servant, whose constant attention to her had given rise to a feeling of strong attachment on the side of the invalid, but who had been the chief actor in the scene of the previous evening. This feeling wore off in the course of a day or two. A few days afterwards, the somnambulism again recurred; and being upon her bed at the time, she immediately began to search for the locket under her pillow. In consequence of its having been removed in the interval (in order that she might not, by accidentally finding it, be led to inquire into the cause of its presence there, of which it was thought better to keep her in ignorance), she was unable to find it; at which she expressed great disappointment, and continued feeling for it, with the remark, "It *must* be there; I put it there myself a few minutes ago; and no one can have taken it away." In this state, the presence of S—— renewed her previous feelings of anger; and it was only by sending S—— out of the room that she could be calmed and induced to sleep.

This patient was the subject of many subsequent attacks, in every one of which the anger against S—— revived; until the current of thought changed, no longer running exclusively upon what related to her brother, but becoming capable of direction by *suggestions* of various kinds presented to her mind, either in conversation, or, more directly, through the several organs of sense. On one occasion, the attack having come on whilst she was alone, she managed to make her way down stairs, along a passage, and out into the garden by a back-door, although completely paraplegic,—a very curious instance of sleep-*walking*. So nearly did her condition, in some of these attacks, approach the waking state, that the case might then be almost regarded as one of *double consciousness*,—that very curious affection, of which the subject seems to lead two distinct lives, A and B, in neither remembering what takes place in the other, but each state being, as it were, continuous with itself.

The preceding case is well adapted to illustrate the general characters of the somnambulistic condition: we have now to notice some of those peculiar phenomena which are presented in individual cases. The first of these to which we shall advert, is the extraordinary exaltation of the sensibility to external impressions through one or more of the organs of sense; which would seem to result, in some instances, from the concentration of the attention upon that one class of impressions, but which, in other cases, is independent of any such state of attention.* We have ourselves been particularly struck with this, in the somnambulism induced by the "hypnotic" process of Mr. Braid, to which we shall presently refer. We have seen unequivocal proof that the sense of smell has been exalted to an acuteness at least equalling that of the most keen nosed ruminant or carnivorous animal; that the sense of hearing has been rendered equally acute; and that the sense of touch has been exalted, especially in regard to temperature, to a degree that would be scarcely credible, were not the phenomena in perfect keeping with the exaltation of the other senses. We are not aware that the sense of sight has ever been thus acted on. In most somnambulists it is altogether suspended; and those who claim to possess the power of clairvoyance, reading words inclosed in opaque boxes, &c., do not refer their power of doing so to any unusual acuteness of their visual organs, but attribute it to the development of an entirely new faculty, for the operation of which any such optical instrument as the eye is altogether unnecessary. Among the senses most commonly exalted in somnambulism, is that "muscular sense" by which all our voluntary movements are guided; and this seems to be so much increased in acuteness, as quite to replace the visual sense, in the performance of many of those operations for which sight is ordinarily requisite. Thus we find that sleep-walkers make their way over the roofs of houses,

* The young lady whose case we have just detailed, exhibited, in a former attack of nervous disorder, a most extraordinary acuteness of the auditory sense, so that it was difficult to prevent her from hearing everything that passed in the house. Of a conversation held in an ordinary tone, in a room two stories below, she could hear every word as distinctly as if it had passed in her own chamber. Yet she did not suffer pain, as might have been expected, from the excessive loudness of ordinary sounds.

steadily traverse narrow planks, and even clamber precipices; and this with far less hesitation than they would do in the waking state. The fact seems to be, that they are utterly unconscious of the danger they are incurring; and that the whole attention being fixed without any distraction upon the indications of the muscular sense, the requisite movements are performed under its guidance with steadiness and certainty. So, again, it is well known that somnambulists will write with their usual degree of neatness and regularity, when prompted to do so either by their own train of thought, or by some suggestion from without; and this, when it is perfectly certain that they cannot see. We have ourselves witnessed this in hypnotic experiments on two individuals, and made quite sure that vision could not be affording any assistance, by holding a large book between the eyes and hand of the writer. Not only were the lines well written, and at the proper distances, but the *i*'s were dotted and the *t*'s crossed; and in one instance, the writter went back half a line to make a correction, crossing off a word, and writing another above it, with as much correctness as if he had been guided by vision. The guidance of the muscular sense in this case may be compared to that which we ourselves receive from it, when ascending or descending a pair of stairs, or traversing a passage, to which we have previously been accustomed, in the dark; we know when we have come to the end, without having counted our steps, or in any way observed our progress, simply by the information we receive through the muscular sense. To the suspension, complete or partial, of the activity of one or more of the organs of sense, which may occur spontaneously, or may be induced by calling off the attention from it, reference has already been made.

The next point to be noticed is the readiness with which the train of thought may be guided, during the state of somnambulism, by the principle of *suggestion*. This is more, perhaps, the case in *artificial* or *induced* than in *natural* somnambulism; for in the latter there is frequently, as already pointed out, some dominant idea or set of ideas, from which the attention of the somnambulist cannot easily be distracted. In the former, the mind is like a weathercock, without the least fixity or self-control, but liable to be turned in any direction by the impressions to which it is subjected. It is one of the most curious and important of Mr. Braid's discoveries, that the suggestions conveyed through the muscular sense are among the most potent of any in determining the current of thought. Let the face, body, or limbs be brought into the attitude expressive of any particular feeling, or into a condition at all corresponding with that in which they would be placed for the performance of any voluntary action, and the corresponding mental state is at once called up. Thus, if the hand be placed upon the vertex, the somnambulist will frequently, of his own accord, draw his body up to its fullest height, and throw his head slightly back; his countenance then assumes an expression of the most lofty pride, and his whole mind is obviously possessed by the feeling. Where the first action does not of itself call forth the rest, it is sufficient to straighten the legs and spine, and to throw the head somewhat back, to arouse the feeling and the corresponding expression to its full intensity. During the most complete domination of this emotion, let the head be bent forward, and the body and limbs gently flexed; and the most profound humility then takes its place. So, again, if the angles of the mouth be gently separated from one another, as in laughter, a hilarious disposition is immediately generated; and this may be immediately made to give place to moroseness, by drawing the eyebrows towards each other and downwards upon the nose, as in frowning. Not only have we witnessed all these effects repeatedly produced upon numerous "hypnotised" subjects, but we have been assured by a most intelligent friend who has paid special attention to the psychological part of this enquiry, that having subjected himself to Mr. Braid's manipulations, and been only partially thrown into the "hypnotic" state, he distinctly remembers everything that was done, and can retrace the uncontrollable effect upon his state of mind which was produced by this management of his muscular apparatus.

So, again, not merely emotional states but definite ideas are thus excitable. Thus, if the hand be raised above the head, and the fingers are flexed upon the palm, the idea of climbing, swinging, or pulling at a rope is called up; if, on the other hand, the fingers are flexed when the arm is hanging down at the side, the idea excited is that of lifting a weight; and if the same be done when the arm is advanced forwards in the position of striking a blow, the idea of fighting is at once aroused, and the somnambulist is very apt to put it into immediate execution. On one occasion on which we witnessed this result, a violent blow was struck, which chanced to alight upon a second somnambulist within reach; his combativeness being thereby excited, the two closed, and began to belabour one another with such energy, that they were with difficulty separated. Although their passions were at the moment so strongly excited, that even when separated they continued to utter furious denunciations against each other, yet a little discreet manipulation of their muscles soon calmed them, and put them into perfect good humour. The power of the operator, in regulating the state of mind of such somnambulists, is almost unlimited; and surpasses the credibility of those who do not discern the very simple principle on which it is exercised. The facility with which particular feelings or ideas may thus be excited, will of course be dependent in part on the previous character and habits of the somnambulist.

Again, a very uncommon degree of power

may be determined to particular muscles, as Mr. Braid has shown, either by a suggestion (so to speak) applied directly to themselves, or by the induction of such a mental state as shall be most fitted to call them into energetic operation. Thus the extensor muscles of a limb may be excited to contraction by gently rubbing or pressing the surface above them; and this contraction may not merely raise the limb, but may keep it fixed in a cataleptiform manner for a much longer time than any voluntary effort could accomplish. This contraction may be caused to give way at any moment, by gently wafting a current of air over the same surface, which seems to call off the attention from the muscles to the skin. In order to throw an extraordinary degree of power into a group of muscles by a mental process, all that is required is to suggest the action, and to assure the somnambulist that it can be accomplished with the greatest facility if he will only determine to do it. Thus, we have seen one of Mr. Braid's hypnotised subjects, a man remarkable for the poverty of his muscular development, lift a twenty-eight pound weight upon his little finger alone, and even swing it round his head, — upon being assured that it was as light as a feather. We have every reason to believe that the personal character of this individual placed him above the suspicion of deceit; and it is obvious that if he had *practised* such a feat (which very few, even of the strongest men, could accomplish without practice), the effect would have been visible in his muscular development. The same individual declared himself altogether unable to raise a handkerchief from the table, after many apparently strenuous efforts; having been assured that its weight was too great for him to move. Of course, there was not an equal proof of the absence of deception in this second case as in the first; but if the reality of the first be admitted, there need be no difficulty in the reception of the second, since both are manifestations of that mental condition which has been shown to be so characteristic of this state, — the possession of the mind by a dominant idea, which, when infused into it (as it were) by the principle of suggestion, directs the bodily movements, and is not corrected by the teachings of ordinary experience, or even by present sensations, if the mental assurance be strong enough to cause these to be disregarded.

Of the *causes* of somnambulism, no very definite account can be given. In some persons this state recurs frequently, or even habitually; in others occasionally. In the case formerly detailed, its access might generally be traced to some strong mental emotion. Those in whom it presents itself *spontaneously* are said to be *natural* somnambulists; but it may be *induced*, not merely in them, but in others who have manifested no predisposition to it, by certain *artificial* procedures. In many cases this may be effected through the mind alone, the simple *expectation* of the result being sufficient to bring it about. Thus the Abbé Faria was accustomed to induce somnambulism by placing his patient in an arm-chair, and then, after telling him to shut his eyes and collect himself, pronouncing in a strong voice and imperative tone the word "dormez," which generally produced on the individual an impression sufficiently strong to give a slight shock, and occasion warmth, transpiration, and sometimes somnambulism. — The following case is another illustration of the effect of this state of expectation, acting in concurrence with a fixed position. The subject of it was a lady who had previously shown great susceptibility to the "mesmeric" and "hypnotic" processes. "We now requested our patient to rest quietly at the fire-place, to think of just what she liked, and look where she pleased, except at ourselves, who retreated behind her chair, saying that a new mode was about to be tried, and that her turning round would disturb the process. We very composedly took up a volume which lay on the table, and amused ourselves with it for about five minutes; when, on raising our eyes, we could see, by the excited features of other members of a little party that were assembled, that the young lady was once more *magnetised.* We were informed by those who had attentively watched her during the progress of our little stratagem, that all had been, in every respect, just as before. The lady herself, before she was undeceived, expressed a distinct consciousness of having felt our unseen passes streaming down the neck."*

Perhaps the most effectual of all modes of inducing somnambulism is that discovered by Mr. Braid, and practised extensively by him under the designation of hypnotism.† The following is his description of his mode of inducing it, and of the phenomena attending its production. "Take any bright object (I generally use my lancet-case) between the thumb and fore and middle fingers of the left hand; hold it from about eight to fifteen inches from the eyes, at such position above the forehead as may be necessary to produce the greatest possible strain upon the eyes and eyelids, and enable the patient to maintain a steady fixed stare at the object. The patient must be made to understand that he is to keep the eyes steadily fixed on the object, and the mind riveted on the idea of that one object. It will be observed that, owing to the consensual adjustment of the eyes, the pupils will be at first contracted; they will shortly begin to dilate, and after they have done so to a considerable extent, and have assumed a wavy motion, if the fore and middle fingers of the right hand, extended and a little separated, are carried from the object towards the eyes, most probably the eyelids will close involuntarily, with a vibratory motion. . . . After ten or fifteen seconds have elapsed, by gently elevating the arms and legs, it will be found

* Brit. and For. Med. Rev., vol. xix. p. 477.

† Neurypnology, or the Rationale of Nervous Sleep, considered in relation with Animal Magnetism, &c., by James Braid, M. R. C. S. E., &c.

that the patient has a disposition to retain them in the situation in which they have been placed, if he is intensely affected. If this is not the case, in a soft tone of voice desire him to retain the limbs in the extended position, and thus the pulse will speedily become greatly accelerated, and the limbs, in process of time, will become quite rigid and involuntarily fixed. It will also be found that all the organs of special sense, excepting sight, including heat and cold, and muscular motion or resistance, and certain mental faculties, are at first prodigiously exalted ; such as happens with regard to the primary effects of opium, wine, and spirits. After a certain point, however, this exaltation of function is followed by a state of depression, far greater than the torpor of *natural* sleep. From the state of the most profound torpor of the organs of special sense, and tonic rigidity of the muscles, they may at this stage be *instantly* restored to the *opposite* condition of extreme mobility and exalted sensibility, by directing a current of air against the organ or organs we wish to excite to action, or the muscles we wish to render limber, and which had been in the cataleptiform state. By mere repose the senses will speedily merge into the original condition again." We have ourselves frequently witnessed the induction of somnambulism after this method ; and whilst fully admitting its potency, we are bound to say that the almost invariable success which it has in the hands of Mr. Braid himself, appears partly due to the mental condition of the patient, who is usually predisposed to the " hypnotic " state by the expectation of its certain production, and by the assurance of a man of determined will that it *cannot* be resisted. When the hypnotic state, however, has been induced a few times in the manner just described, the subject can usually send himself to sleep very readily by looking at his own finger, brought sufficiently near the eyes to occasion a sensible convergence of their axes ; or even by simply standing still, and fixing the eyes on a distant point. In all cases, the fixation of the eyes is the circumstance of most importance; although the withdrawal of other stimuli has a decided influence in favouring the production of the effect. The peculiar condition of the *muscular* sense, as felt through the ophthalmic branch of the fifth pair, seems to have a closer relation with the subsequent state than has the condition of the visual sense; for the same effect may be produced at night, or in blind persons, if the eyes can be kept in a fixed position, especially in one that produces a feeling of muscular tension. And it seems to be in facilitating this, that the sense of sight comes into play in the operation just described. How far the mode in which the somnambulism is produced has an influence upon its phenomena, it may not be very easy to determine. For an account of these peculiarities, we must refer to Mr. Braid's treatise already quoted ; but we may cite the following, as having ourselves repeatedly witnessed it and satisfied ourselves of its reality. " The remarkable fact that the whole senses may have been in a state of profound torpor, and the body in a state of rigidity, and yet by very gentle pressure over the eye-balls the patient shall be instantly roused to the waking condition, as regards all the senses and mobility of the head and neck, in short, to all parts supplied with nerves originating above the origin of the fifth pair, and those inosculating with them,—whilst they will not be affected by simple mechanical appliance to other organs of sense,—is a striking proof that there exists some remarkable connection between the state of the eyes, and condition of the brain and spinal cord, during the hypnotic state. Another remarkable proof to the same effect is this ; Supposing the same state of torpor of all the senses, and rigidity of the body and limbs, to exist, a puff of air or a gentle pressure against *one* eye will restore sight to *that* eye, and sense and mobility to *one half of the body*—the same side as the eye operated on ;—but will leave the other eye insensible, and the other half of the body rigid and torpid as before."*

We consider that the experimental researches of Mr. Braid throw more light than has been derived from any other source upon the phenomena of *Mesmerism*. That there is much of reality mixed up with much imposture in these phenomena, is a conclusion at which most candid persons have arrived who have given their attention to them ; and we have little doubt that a searching investigation, carried on under the guidance of his results, would lead to something like a correct discrimination between the two. The induction of mesmeric somnambulism appears to us to be fully explicable by the facts we have previously stated, as to the influence of the mental condition of the patient,—namely, the state of expectation, and the additional confidence derived from the mental impression produced by the operator,—and as to the effect of the fixation of vision. The ordinary phenomena of the mesmeric somnambulism itself are in most respects identical with those of hypnotism, except in this particular,—that there seems to be a peculiar relation between the somnambulist and the mesmeriser, which does not exist between the somnambulist and any other individual, excepting one who is *en rapport* with the mesmeriser. This relationship may perhaps be not unreasonably regarded as the result of a dominant idea, which possessed the mind at the moment of falling asleep, and which continued to influence it so long as the somnambulism lasts. We have examined into the history of many cases, in which it was affirmed that mesmeric sleep was induced without any consciousness on the part of the subject of it that any influence was being exercised; but we have never been able to satisfy ourselves that such was unequivocally the case. When the patient was *expecting* the performance,

* Op. cit. p. 64. *note.*

and was waiting in quiescence for its commencement, the expectation alone was sufficient to induce the sleep. When the patient had *no* such expectation, all attempts to produce the sleep, that have come to our knowledge, have completely failed. Hence we are strongly inclined to the belief that the relation between the mesmeriser and the somnambulist is one of a purely mental character, and not the result of any new physical power. With regard to what have been termed the "higher phenomena" of mesmerism, we believe that without regarding them as the result of intentional deception, most of them are capable of receiving a very simple explanation on the principles already laid down, — namely, that in the state of somnambulism the senses, or some of them, are often endowed with a wonderful acuteness, which causes the mind to be acted on by impressions that might be affirmed to be too faint to be perceived; and that these impressions will suggest trains of thought, and give rise to respondent actions, which are frequently of a kind that the will *could* not produce. As to the reality of the so-called *clairvoyance*, repeated personal examination has led us to a negative conclusion. The sources of fallacy arising from the causes we have mentioned, as also from the tendency on the part of the bystanders to afford assistance by asking "suggestive" or "leading questions," and from their disposition to interpret the least shadow of a resemblance into a complete coincidence, are such as greatly to diminish the wonder that a firm belief in the reality of these phenomena should be entertained by many persons of excellent judgment and great discrimination and acuteness as to all ordinary matters.

A state in most respects corresponding with natural somnambulism is frequently induced by the inhalation of ether, chloroform, and other anæsthetic agents. Instead of being completely comatose, the patient, though quite unconscious of pain, may be awake to external impressions received through some of his organs of sense, so as during an operation to obey the directions given him in order to facilitate its performance; and yet he shall be completely unaware of what has taken place when the effects of the anæsthetic agent have gone off. But even the sense of pain may not be extinguished, and the patient may scream and struggle even more violently than in the waking state; and yet the whole is subsequently forgotten, or is remembered only as a troubled dream. It was further to be noticed that, during the employment of ether, the state of the nervous system induced by it appeared to be much influenced by the previous degree of confidence entertained by the patient as to its results. The more potent action of the chloroform, however, has prevented this influence from being so apparent.

(*W. B. Carpenter.*)

SMELL. — The sense through which we take cognizance of odours.

Of the nature of odorous emanations nothing is certainly known. They are generally supposed to consist of material particles of extreme minuteness, detached from the odorous body, and dissolved or suspended in the air. This idea derives its chief support from the facts that most odorous substances are volatile, that is, their loss of weight, when exposed to the air, shows that their particles really diffuse themselves through it, — that most strongly odorous substances are extremely volatile—and that circumstances which increase the volatility of such substances also augment their odorous powers. These general statements, however, are not without their exceptions. Thus, in the first place, we do not find that many gaseous substances are truly *odorous;* the pungent, irritating qualities, by which many of them are distinguished, not being perceived through the sense of smell but through that of touch. Again, although it is true that a great number of volatile liquids are odorous, the strength of their scent bears no constant proportion to their respective volatility; and water, which is so constantly diffused through the air, has no odorous property. And with regard to solids, we find that although some of those which are most strongly odorous are also volatile (such as camphor), yet this is not by any means universally the case; for it has been proved by experiment that no diminution in weight can be ascertained to take place in musk or amber, although they have been freely exposed to the atmosphere for many years, and have imparted their perfume to an almost incalculable volume of air. These considerations have led some philosophers to suppose that odorous emanations are not *material*, but *dynamical:* — in other words, that the impressions made upon our olfactory organ do not result from the contact of diffused particles detached from the odorous body; but that they are effected by a change propagated through the atmosphere or other medium, in the same manner as sound is produced by undulations that originate in the sonorous body, and are transmitted onwards, through some material medium, to the organ of hearing. There are strong objections, however, to this hypothesis. In the first place, we find that odours are not perceived unless the air, gas, or liquid in contact with the olfactory surface is, or has been, in direct continuity with the odorous body; the interposition of any substance which prevents the actual passage of the odoriferous medium being sufficient to prevent the transmission of the odour. This is by no means the case in regard to sound, or to any other agent that is known to be dynamically propagated; for we find many substances which are capable of *conducting* these agents, that is, of transmitting their influence through unlimited spaces; and this may be accomplished in spite of any number of interruptions in their continuity, provided the chain of conducting substances be complete. Thus, sonorous vibrations may be transmitted from air to liquids, from liquids

to solids, from air to solids, from solids to air, &c.; and many such changes usually take place, before the vibrations originating in a sonorous body are communicated to the sentient extremities of the auditory nerve. The same is the case with heat, light, electricity, and other agents whose transmission is believed to be dynamical: that it is *not* the case in regard to odorous emanations must be regarded, therefore, as a powerful argument against the idea of their dynamical nature. Another argument may be derived from the well-known fact, that odorous emanations require such a *time* for their propagation, as corresponds rather with the *diffusion* of the odoriferous medium itself, than with the mere *conduction* of vibrations. Thus, in a house in which free communication is established throughout by passages, staircases, &c., but in which the course of air is not very direct from one part to another, any strong odour set free in one spot will be *gradually* diffused through the whole house, the rapidity being governed by the circumstances which favour or obstruct the movement of air. On the other hand, the transmission of sonorous undulations, which merely throw the air into vibration, is not dependent upon its movement, and is, indeed, but little influenced by it. This argument is, perhaps, yet more cogent than the former, and may be regarded as conclusive against the dynamical theory of odours.

It is not difficult to explain many of the apparent inconsistencies which attend the material theory. The varieties of the olfactive power among human beings are quite sufficient to prove, that a substance which is strongly odorous to one individual may not produce any impression on the smell of another, whose scent for other substances may nevertheless be very acute. And there is strong reason to believe that there is a great diversity in this respect amongst different species of animals, some appearing entirely insensible to odours which strongly affect others. That *we* do not appreciate an odour, therefore, is no proof of its non-existence; and we have no right to say of any volatile or gaseous substances, that they are not odorous, but simply that they are not odorous *to us*. Again, the sense of smell, like the other senses, is rather *relative* than *positive*; that is to say, it rather estimates a *change* in the condition of the surrounding medium, than its actual permanent state. This is fully proved by the fact that persons who habitually dwell amongst odours of any one kind, become, in time, entirely insensible to them, although their olfactive sense may remain of its full acuteness in regard to any different scent. This being the case, we at once perceive that water, oxygen, nitrogen, and carbonic acid *could* not, in accordance with the general laws of sensation, possess any odour to animals whose organs of smell are constantly imbued with them. We shall presently find that the moisture of the olfactory membrane is a necessary condition of its functional power; and thus neither fishes, which have their olfactory surface constantly bathed in water, nor air-breathing animals, whose pituitary membrane is lubricated with it, could take cognisance of any odorous properties which it might really possess. In like manner, the nasal cavities of animals being continually filled with a mixture of oxygen, hydrogen, and carbonic acid, these gases cannot excite the olfactive sense; whilst on the other hand, we can easily imagine that if animals were adapted to breathe hydrogen or its strongly odorous compounds, they would be insensible to the latter, whilst they might distinguish oxygen, nitrogen, or carbonic acid by their respective odours, just as readily as *we* distinguish phosphuretted, sulphuretted, or carburetted hydrogen.

Although it is through the atmosphere that odorous emanations are most readily conveyed, yet there can be no reasonable doubt that they may be transmitted through water also. Thus we find fishes provided with a complex organ of smell, which seems to be of considerable importance in directing them towards their prey. This may be inferred, not merely from the fact that the olfactive ganglia and nerves are of large size relatively to the rest of the encephalon, but also from the circumstance, well known to fishermen, that many fish are particularly attracted by odorous bait. Some anglers are even in the habit of scenting their bait with essential oils, in order to render it more alluring.

The general structure of the *organ of smell* in man has already been described (Nose); but some particulars recently ascertained by Messrs. Todd and Bowman respecting the minute anatomy of the pituitary membrane, and the structure and distribution of the olfactory nerve, are too important to be passed by. That the true sense of smell is specially, if not exclusively, the endowment of the upper portion of the organ, has been inferred by anatomists from the limited distribution of the olfactory nerve, and by physiologists from the fact that odours are only perceived strongly when the odoriferous air is drawn into the upper part of the cavity. The lower part of the nasal cavity is properly to be regarded as the orifice of the respiratory passages: it is extremely sensitive to *irritants*, but it does not participate in the discrimination of *odours* properly so called; and its mucous membrane is covered with a ciliated columnar epithelium. On the other hand, the limits of the olfactive region "are distinctly marked by a more or less rich sienna-brown tint of the epithelium, and by a remarkable increase in the thickness of this structure compared with the ciliated region below; so much so, that it forms an opaque soft pulp upon the surface of the membrane, very different from the delicate, very transparent film of the sinuses and lower spongy bones. The epithelium, indeed, here quite alters its character, being no longer ciliated, but composed of an aggregation of superposed nucleated particles, of pretty uniform appear-

ance throughout; except that, in many instances, a layer of those lying deepest, or almost deepest, is of a darker colour than the rest, from the brown pigment contained in the cells. These epithelial particles, then, are not ciliated; and they form a thick, soft, and pulpy stratum, resting on the basement membrane. The deepest layer often adheres after the others are washed away." The vessels of the olfactive membrane in the fœtus present a regular series of papillary loops; but these cannot be seen in the adult. "The olfactory filaments form a considerable part of the entire thickness of the membrane, and differ widely from the ordinary cerebral nerves in structure. They contain no white substance of Schwann, are not divisible into elementary fibrillæ, are nucleated and finely granular in texture, and are invested with a sheath of homogenous membrane." These nerves thus rather correspond with the gelatinous fibres, than with the ordinary tubular fibres of the trunks and branches of true nerves; and they are regarded by the authors as direct continuations of the vesicular matter of the olfactory bulb or ganglion. "Although these nucleated olfactory filaments lie in great abundance under the mucous membrane of the olfactory region, we have been quite foiled in our attempts to trace their ultimate distribution in the membrane, and the difficulty is attributable to their want of the characteristic white substance. Their elongated nuclei render the larger branches unmistakeable; but if these become resolved at last into fibrous elements, the nuclei cease to be distinct from those of the numerous nucleated tissues which they traverse." "We are averse from speculating prematurely on the meaning of anatomical facts; but as some hypothesis will intrude itself, we would venture to hint that the amalgamation of the elements of the peripheral part of the nervous apparatus in the larger branches, and probably in the most remote distribution, as well as the nucleated character indicative of an essential continuity of tissue with the vesicular matter of the lobe, are in accordance with the oneness of the sensation resulting from simultaneous impressions on different parts of this organ of sense, and seem to show that it would be most correct to speak of the first pair of nerves as a portion of the nervous centre put forward beyond the cranium, in order that it may there receive, as at first hand, the impressions of which the mind is to become cognisant."* It has also been remarked by the same excellent observers †, that on the septum narium and spongy bones bounding the direct passage from the nostrils to the throat, the lining membrane is rendered thick and spongy by the presence of ample and capacious submucous plexus of both arteries and veins, of which the latter are by far the larger and more tortuous. And they surmise, with much probability, that the chief use of these may be to impart warmth to the air, before it enters the proper olfactive portion of the cavity; as well as to afford a copious supply of moisture, which may be exhaled by the abundant glandulæ seated in the membrane. "The remarkable complexity of the lower turbinated bones in animals with active scent, without any ascertained distribution of the olfactory nerves upon them, has given countenance to the supposition that the fifth nerve may possess some olfactory endowment, and seems not to have been explained by those who rejected that idea. If considered as accessory to the perfection of the sense in the way above alluded to, this striking arrangement will be found consistent with the view which thus limits the power of smell to the first pair of nerves." *

The olfactive organ, in other air-breathing Vertebrata, corresponds with that of man in all the essential particulars of its structure; being a cavity opening anteriorly upon the face by the external or anterior nares, and posteriorly into the upper part of the pharynx by the internal or posterior nares. It may thus be considered as the entrance of the respiratory passages, which is dilated for the extension of the olfactive membrane; or, perhaps, it would be more correct to speak of it as a diverticulum from the commencement of the respiratory tube, since, as we have seen, the proper olfactive organ does not extend into that portion of the cavity which is placed in a direct line between the anterior and posterior nares. The development of the olfactive organ, as measured by the size of the olfactory ganglia and nerves, and by the extent of the surface over which these are distributed, varies greatly in different tribes; and details must be sought on this subject under the respective names of the classes and orders of vertebrata. The chief departure from the ordinary type is observable in the case of the Cetacea, in which the nasal cavity is almost entirely devoted to the purposes of respiration, and to the ejection of the water taken in by the mouth with the food. To animals which seek their prey in the water, an organ of smell, adapted to take cognisance of odorous emanations contained in the inspired air, would obviously be entirely useless; and it is probable that whatever olfactive power they possess is called into exercise by the passage of the water that is spouted through the nostril. The ordinary statement that the Cetacea are entirely destitute of olfactive ganglia and nerves, and that they must therefore be entirely devoid of the sense of smell, is true only of the *Delphinidæ*, or that division of the order which includes the dolphins and porpoises; for the *Balænidæ*, or proper whales, do possess olfactive nerves, although these are comparatively of small size; and in the *Manatidæ*, or herbivorous whales, which properly belong rather to the Pachydermata

* Physiological Anatomy and Physiology of Man, vol. ii. pp. 5—11.

† *Op. cit.* p. 3.

* Op. cit. p. 12.

than to the Cetacea, the olfactive apparatus is formed after the usual type.

In Fishes, however, the plan is altogether changed, the organ of smell being no longer connected with the respiratory passages, but disposed in a cavity peculiar to itself, which opens externally by anterior nares, but has no internal communication by means of posterior orifices.

No distinct organ of smell has yet been discovered in the Dibranchiate Cephalopoda; but in the *Nautilus*, a peculiar laminated organ, strongly resembling the olfactive organ of fish, has been considered by Prof. Owen as an olfactory apparatus. The inferior Mollusca would seem to be altogether destitute of special organs of smell; but as there is much reason to believe that some of them, especially the terrestrial Gasteropods, are guided to their food by its scent, it would not seem improbable that some part of the soft spongy glandular mantle, in which the entire body is enveloped, may be adapted to take cognizance of odorous emanations; or that in the air-breathing species, the entrance to the respiratory sac should be endowed with a low degree of this power.

There is ample reason to infer, from observations of the actions of Insects, that these animals possess the olfactive power in no inconsiderable degree; and yet no special organ for this sense has hitherto been satisfactorily made out. That many insects are guided to their food, to the proper nidus for their eggs, and to the opposite sex of their own species, and are even informed of the proximity of their natural enemies, by odorous emanations, can scarcely be doubted by any one who watches their habits, and who experiments upon their actions under a variety of circumstances. Thus, the flesh-fly will be attracted by the odour of decomposing meat, when this is completely hid from its sight; and will deposit its eggs on the envelope with which it may be covered. On the other hand, the same insect is deceived by the odour of the *Stapelia*, or carrion-flower, and is led to deposit its eggs in its petals. Again, many male insects will show that they are aware of the proximity of their females, when the latter are shut up in boxes, so as to be hid from their sight, and utter no sound. And in like manner, when a predaceous insect or spider is shut up in a box that gives a sufficiently free passage to air, the small insects on which it preys will manifest their alarm at its proximity, and will endeavour to make their escape. Some entomologists have supposed the seat of the olfactory sense of insects to be in their antennæ, others in the palpi, and others in the entrances to the air-tubes. No evidence can be adduced in favour of either of these suppositions that is satisfactory enough to prove it, and we have little other guide at present than *à priori* probability. In regard to the last of the three suppositions, however, it may be remarked that all analogy opposes the idea that the true olfactory apparatus should be thus scattered amongst the several segments of the body; and the experiments which appear to favour it really lead to no other conclusion than this, that acrid or irritating vapours, taken in through the breathing-pores, may excite reflex movements which seem destined to expel them, or to withdraw the body from them. Such movements resemble those of coughing and sneezing in man, which are excited through the nerves of common sensation, and not through the first pair; and they do not in the least indicate, therefore, that the sense of smell is in any way connected with the respiratory apparatus of insects, myriapods, &c. The use which many insects may be seen to make of their palpi, in taking cognizance of their food without actually touching it, suggests the idea that they are the true olfactive organs; and this idea is borne out by the fact, that these organs terminate, in the living state of many insects, in soft bulbous expansions, which shrivel up and become horny in the dead specimen, thereby obscuring their real character. On the other hand, many insects are furnished with soft membranous appendages at the base of their antennæ, which seem equally adapted to perform this function. And it is asserted by Dugès *, that insects whose antennæ had been cut off did not manifest the same cognizance of the neighbourhood of odorous substances, as did others of their kind whose antennæ had been left entire. It would seem not a very improbable supposition that, as the antennæ and palpi are organs of a similar class, the sense of smell may not be localised in one or other of them constantly; but that it may be assigned to one or the other, according to the modifications they may respectively require for the performance of their other offices. The same doubt exists in regard to the olfactive organ of the Crustacea. The manner in which crabs and lobsters are attracted by odorous bait placed in closed traps, makes it almost certain that they must possess some sense of smell; and the most probable locality of the organ would seem to be a cavity discovered by Rosenthal at the base of the first pair of antennæ.

As to the existence or absence of the sense of smell in the lower Invertebrata, nothing can be definitely stated.

Nerve of smell. — That the *first pair* of cranial nerves is the true *olfactive*, and that through it alone are the proper odorous emanations perceived, would seem a legitimate inference from the fact, that its development in vertebrated animals is constantly proportionate, *cæteris paribus*, to the acuteness of the sense; and that it is chiefly distributed to that part of the nasal cavity, which is most distinguished by the possession of this endowment. This inference is fully borne out by the facts supplied by experiment and pathological observation. The division of the olfactory nerves in animals evidently produces a complete destruction of the power of perceiving odours; although they are still affected

* Physiologie Comparée, tom. i. pp. 160, 161.

by irritating vapours. They do not immediately perceive these vapours, however, but seem indifferent to them at first, and then suddenly and vehemently avoid them as soon as the Schneiderian membrane becomes irritated. It was maintained by Magendie that the fifth pair in some way furnishes conditions requisite for the enjoyment of the sense of smell; this sense being destroyed, according to his assertion, by section of its trunk. His experiments, however, were made with irritating vapours which excite sternutation; and he inferred the loss of the sense of smell from the absence of the automatic movements which these vapours normally excite. This inference was altogether unjustifiable; since the experiments in question afford no proof that the power of perceiving *odours*, with which the excitement of automatic movements does not appear to be in any way connected, is destroyed by section of the fifth pair. A diminution in the acuteness of the true sense of smell, however, appears to be a usual result of paralysis of the fifth pair; but this is readily accounted for by the diminution of the normal secretion of the pituitary membrane, by which its surface is deprived of the moisture that is necessary for the exercise of its sensory powers. The difference in the endowments of the first and fifth pairs of nerves, and the speciality of the former, are further marked by the result of mechanical irritation of their trunks and branches. Such irritation of the first pair excites no muscular movement, either direct or reflex, and it produces no indication of pain. On the other hand, irritation of the nasal branches of the fifth pair is obviously attended with violent pain, and excites various automatic muscular movements. Lastly, it has been found that in cases of deficiency or loss of the sense of smell, some abnormal condition of the olfactive nerves or ganglia has existed; and the same kind of change has been discovered in cases in which *subjective* sensations (*i. e.* sensations not originating in external objects) had existed during life.

Conditions of the exercise of the sense.—The first condition requisite for the exercise of the sense of smell, is the contact of the odoriferous medium with the olfactive surface. This may be favoured or prevented by a variety of circumstances. Thus, odours are more rapidly transmitted by air in motion than by air at rest; but they only proceed in the direction of the movement: and hence animals possessed of the keenest scent, which would be alarmed by the presence of a human or other foe a mile off on the windward side, may be approached within a short distance on the leeward, when a fresh breeze is stirring. The odoriferous medium must not only be brought *to* the nose, but it must be introduced *within* the olfactive cavity. This is usually accomplished by the ordinary movement of inspiration, which draws a current of air through the nose; but as the current chiefly passes through the lower part of the nasal cavity, to which the olfactive nerve is very sparingly or not at all distributed, the full use of the sense of smell is not thus gained. It is only by making a series of short and *quick* inspirations,—the effect of which seems to be, to empty the *whole* nasal cavity of the air it previously contained, and thus to cause the newly-inspired air to pass forcibly into its upper part, instead of merely streaming through the passage between the anterior and posterior nares,—that we employ our olfactive powers to the best advantage. This movement, combined with the direction of the nostrils towards the source of the odour, and with the dilatation of their orifices by the muscles adapted for that purpose, constitutes the *active* exercise of the sense, which may be termed *scenting*. This bears the same relation to ordinary smelling, as feeling bears to touch, listening to hearing, or looking to seeing. The effect of the sensory impression on the mind is further heightened by the attention which is bestowed upon it; and it does not seem improbable that the sensation itself is rendered more acute by an increased determination of blood to the olfactive surface when it is being thus actively employed. On the other hand, the use of this sense may be prevented, not merely by the closure of the nares, anterior and posterior, so as completely to exclude the odoriferous medium, but also by simply refraining from drawing air into the nasal cavity. If we breathe through the mouth only, closing the posterior nares by means of the velum palati, we may avoid being affected by odours even of the strongest and most disagreeable kind; for the nasal cavity being already filled with air, there is no room for the entrance of the odoriferous atmosphere from without; and it may thus be long before the odorous particles come into contact with the olfactive surface.

It is, of course, an essential condition of the exercise of this sense, that the whole nervous apparatus, which forms the essential part of its organ, should be in a state of integrity; and that a free circulation of blood shall take place through the olfactive portion of the pituitary membrane. But, in addition, it is requisite that the epithelial and mucous covering of the membrane be in a normal state. If the surface be too dry, the odorous particles cannot undergo that solution in the fluid in contact with the sentient extremities of the nerves, which seems necessary for the production of an impression on them. On the other hand, when the secretion is too abundant, it interferes with its contact in the opposite manner. And thus it happens that the sense of smell is blunted, both in the primary and secondary stages of an ordinary cold, by the disorder of the secreting surface, independently of the effect which the disturbance of the circulation may have upon the functional power of the olfactive nerve.

Purposes of the sense.—When we take a comprehensive survey of the animal kingdom, we at once perceive that the most *general*, and therefore the most *essential* purpose of the sense of smell, is to make known the pre-

sence of food, to indicate its direction and thus to guide the animal towards it, and to aid in the discrimination of its qualities. We *always* find the olfactive organ placed in the neighbourhood of the mouth; its connection with the respiratory apparatus is by no means so constant. In air-breathing vertebrata, whose olfactive cavity opens into the pharynx, the sense of smell largely participates in that of taste (see TASTE), being the means by which we take cognisance of the *flavours* of sapid bodies introduced into the mouth. Of the importance of this sense in directing animals to their food, it is needless to multiply instances; but we may remark that, from observation of the actions of the human infant, we are well convinced that it is rendered cognisant by smell of the neighbourhood of its nurse, long before it recognises her by sight, and that this sense is its guide in seeking the source of its nutriment. How purely instinctive this action is, — that is, how completely independent of all experience, and entirely dependent upon the provocative sensation, — is well shown by the experiment of Galen, who placed a kid, just dropped, near three vessels, one filled with milk, another with honey, and another with wine; after smelling at all three, it presently began to drink the milk. It would seem to be by the information conveyed through their smell, that bees are induced to fly to pastures at a great distance from their hive; and it would not seem improbable that the sense of *direction*, which is so remarkably displayed by many animals, is the result of the acuteness of their olfactive power. Whilst the chief use of smell to the carnivorous tribes is to guide them to their prey, the herbivorous races, whose food is constantly within their reach, are warned by its means of the neighbourhood of their enemies. The sense of smell is subservient to defence in another way; being the means by which the fœtid scents, emitted by many animals under the influence of alarm, deter their enemies from further pursuit. In nearly all animals, the sexual secretions are more or less odorous; and these would seem to be intended, not merely to contribute to make the sexes aware of each other's proximity, through the sense of smell, but also, in many instances, to serve as a provocative to sexual desire. The odours which are attractive to animals are usually related either to their food or their sexual instinct; but there are cases in which animals seem to delight in odours which have no such relation: thus, cats seem to revel, as it were, in the odour of Nepeta (catmint) or Valerian.

In the air-breathing vertebrata, the sense of smell is, as it were, the sentinel of the respiratory organs, having for its office to take cognisance of the aeriform fluids which enter them, and to give warning of such as are injurious. The contact of *irritating* matters, however, is perceived (as already stated) through the general sense of feeling, not the special sense of smelling; and it is through the fifth pair that the act of sneezing is excited, the purpose of which is to expel such particles from the nasal cavity. The distinction is well seen in some air-breathing invertebrata, whose organ of smell is seated in the head, whilst the impression of irritants on the respiratory surface, exciting reflex movements for the purpose of avoiding or expelling them, is made through the stigmata. Thus M. Dugès relates* that if the stigmata on one side of a decapitated Scolopendra be exposed to an irritating vapour, the body will be immediately flexed in the opposite direction; and that if the stigmata on the opposite side be then similarly irritated, a contrary movement will occur; whilst by exposing the anterior stigmata on one side, and the posterior on the other, to the same irritation, the body will be bent into the form of the letter S.

In man, the sense of smell is not ordinarily so acute as it is in many of the lower animals; yet it is very possible that it may be capable of taking cognisance of a greater *variety* of odours. In the selection of his food, it is to him by no means the infallible guide that it seems to be in many other races; for it not only gives no warning, in many instances, of what is noxious, but renders certain poisonous substances (as, for instance, those charged with prussic acid or the essential oil of almonds) positively attractive. So, again, in regard to the respiratory organs, whilst it gives warning of the presence of certain gases and emanations which are injurious, it takes no cognisance of many others which are not less hurtful. In the ordinary conditions of civilised life, man is not dependent upon his sense of smell for many of the ends which it answers in other animals; hence this sense is altogether subordinate to others, and the want of it is not usually attended with any great inconvenience. But the case is far different among savage tribes, to whom it is as important as it is to other animals in a state of nature, and in whom it seems to acquire, by the constant habit of attention to its indications, a similar acuteness. Thus, it is stated by Humboldt that the Peruvian Indian, in the middle of the night, is informed of the proximity of another individual by his smell, and can distinguish by his smell whether the stranger be an European, an American Indian, or a Negro. It has even been asserted that some other savage tribes of mankind are enabled to follow a track by the scent of the footsteps, like the bloodhound. The sense of smell, moreover, usually acquires great acuteness, when, from deficiency of the other senses, its indications become the chief or only means of recognising bodies not in immediate contact with the individual. Thus, in the well-known case of James Mitchell, who was deaf, blind, and dumb from his birth, it was the principal means by which he distinguished persons, and enabled him at once to perceive the entrance of a stranger. Mr. Wardrop gives the following curious account of the mode in which he exercised this sense, and of

* Op. cit. tom. i. p. 162.

the information which he derived from it:— "There were some people whom he never permitted to approach him, whilst others at once excited his interest and attention. The opinions which he formed of individuals, and the means he employed to study their character, were extremely interesting. In doing this, he appeared to be chiefly influenced by the impressions communicated to him by his sense of smell. When a stranger approached him, he eagerly began to touch some part of his body, commonly taking hold of the arm, which he held near his nose, and after two or three strong inspirations through the nostrils, he appeared to form a decided opinion regarding him. If this was favourable, he showed a disposition to become more intimate, examined more minutely his dress, and expressed by his countenance more or less satisfaction; but if it happened to be unfavourable, he suddenly went off to a distance with expressions of carelessness or disgust. When he was first brought to my house to have his eyes examined, he both touched and smelled several parts of my body; and the following day, whenever he found me near him, he grasped my arm, then smelled it, and immediately recognised me, which he signified to his father by touching his eyelids with the fingers of both hands, and imitating the examination of his eyes which I had formerly made." We learn from the same account, that in selecting his food, he was always guided by his sense of smell, for he never took anything into his mouth without previously smelling it carefully. He always recognised his own clothes by their smell, and refused to wear those which belonged to others.

Sometimes the peculiar acuteness of this sense is restricted to a particular odour or class of odours, these usually proceeding from objects for which there is either a special fondness or a particular aversion. Thus, a gentleman blind from birth, who had an unaccountable antipathy to cats, so that he could never endure the presence of one in his apartment, one day, when in company, suddenly leaped up and exclaimed that a cat was in the room, begging his friends to remove it. It was in vain that, after careful inspection, they assured him that he was under an illusion. He persisted in his assertion, and his agitation continued; and on the door of a small closet being opened, it was found that a cat had been accidentally shut up in it.

With such unequivocal proofs of the acuteness of the sense of smell which may exist in the human subject, the statements made respecting the extraordinary exaltation of the faculty in various forms of somnambulism become less incredible; and the author is fully satisfied, from his own observations upon individuals *hypnotised* by Mr. Braid (see SLEEP), that this exaltation may certainly take place in regard to the sense of smell. In one instance, a glove being placed in the hand of the hypnotised subject, he found out the owner of it without difficulty, from amongst more than sixty persons, scenting at each of them, one after another, until he came to the right individual. And in another case, the owner of a ring was in like manner unhesitatingly found out from amongst a company of twelve.

The information conveyed by the sense of smell is restricted to the *quality* and *intensity* of the odour, and to some general notion of its *direction*. This last, indeed, is rather derived from a comparison of its relative intensity when the face is turned towards different sides, than from any more direct information as to locality furnished by the organ itself. The absence of any consciousness of the part of the olfactory surface specially affected by the impression,—so that, unless the experiment be made, we know not that we are constantly exerting the sense on both sides, the double sensation being perceived as a single one, — is attributed by Messrs. Todd and Bowman *, with much probability, to the peculiar plexiform arrangement of the fibres of the olfactive nerve, and to the want of the isolation usually effected between the fibres by the white substance of Schwann.

Various classifications of odours, founded upon the impressions which they make upon the sense of smell, have been proposed; but they are all liable to the objection, that there seems to be more of individual diversity in regard to the character of olfactory impressions, than with respect to those of any other kind. Many odours, by some persons thought intolerable, are very agreeable to others; thus, assafœtida is known amongst some by the name of "devil's dung," whilst by others it is spoken of as "food for the gods." It was commonly employed by the ancients as a condiment; but the individuals who thus relish it in our own country certainly constitute the exceptions to the mass. So, again, the *fumet* of game, so highly valued by the epicure, is disagreeable to most persons who have not been trained to appreciate it. On the other hand, the aroma of certain flowers, which is peculiarly agreeable to most persons, is by no means so, or perhaps the reverse, to others. Thus, Müller remarks that the smell of mignonette is to him only herb-like; whilst the flower of *Iris Persica* has been pronounced to be of pleasant odour by forty-one out of fifty-four persons, by four to have little scent, by eight to be without all odour, and by one to be ill-scented.†

It more frequently happens, in regard to odours and savours, than with respect to other sensory impressions, that habit renders that agreeable, and even strongly relished, which was at first highly repugnant.

(*W. B. Carpenter.*)

SOFTENING and INDURATION (*Ramollissement et Induration*, — *Endurcissement*, Fr., *die Erweichung und Härtung*, Germ.) are terms used to express a pathological or physiological diminution and increase, of the consistence of the body or its parts.

* Op. cit., p. 12.

† Arnold's Physiology, vol ii. p. 561.

Softening and induration in a physiological sense, refer to those changes which occur in the density of tissues and organs during their development, growth, and decay ; whilst, in a pathological sense, they refer to alterations in the normal consistence, with or without actual molecular change.

In order to be able to distinguish morbid alterations of cohesion, from those which occur in the natural course of things, it is necessary to be well acquainted with the power exercised by age, sex, and idiosyncrasy, in modifying the density of the tissues.

Softening and induration are but relative terms, the standard of consistence is constantly varying, both as regards the whole body, or as regards organs and tissues. In the fœtal state all the tissues are soft, and contain large quantities of fluid; as development proceeds, so do the parts gradually become hard, not all equally so, for certain tissues remain permanently soft in comparison to others, which rapidly increase in density. After birth, the hardening processes still continue, and it is not until the age of puberty is passed, that all the tissues have attained their highest stage of development. But the process of natural hardening is interfered with, or retarded, by peculiar idiosyncrasy and by the influence of sex and occupation ; the general firmness of the tissue of an athlete is greater than that of those, who, although in perfect health, happen to lead inactive and sedentary lives ; it is greater as a general rule in the male than in the female sex, and in the sanguineous than in the lymphatic temperament.

As old age comes on, changes in the consistence of the tissues occur, which are produced by the natural decay to which all organized matter is subject ; thus the cellular tissue, the serous and mucous membranes, the muscles and tendons, bone, the brain and nervous system, and particularly the uterus and ovaries, sometimes acquire a degree of hardness, equal to that which is known to be produced by certain diseases.

Finally, after death the whole organism is affected by forces, which had little or no influence upon it during life ; the tissues are subjected to the macerating influence of their fluids, which may also act chemically upon them. In the natural course of things, softening and putrefaction, and disorganization of the ultimate atoms of our body occur, before they are fitted to be assimilated into other organized structures ; this decay increases as time progresses, and is enhanced by a high state of temperature and exposure to the air. After death, hypostatic congestion of the cellular tissue simulates the appearance that this structure frequently presents, when affected with inflammatory softening ; and the macerating effects of the fluids, which had no such influence during life, are seen in the brain and spinal cord ; whilst the alimentary mucous membrane suffers softening and disintegration from the peculiarities of the fluid usually secreted by it. By recognising then the normal alterations of cohesion, and those arising from post mortem causes, the attributes of morbid softenings will become perfectly apparent.

Softening and induration are said to exist without any structural change ; such is not generally the case, indeed it is exceptional, and were such a state only to be properly termed softening and induration, many of the most important and interesting pathological facts would be unaccounted for. Softening and induration are produced by a variety of causes, and frequently co-exist in the same organ, or one may supervene on, or cause, the other.

Both softening and induration may be produced by inflammation leading, on the one hand, to effusion of serum and pus, and on the other to the deposition and subsequent contraction and hardening of coagulable lymph ; the one appears to be the result of acute, and the other of subacute, inflammatory action. Active sanguineous congestion produces in some organs the sensation of diminished consistence, whilst in others, especially in those surrounded by a dense fibrous tissue as the testicle, hardening results. In softening, the effused product of inflammation, appears not only to break down the structure by infiltration, but also by its pressure to impede the usual nutrition of the part.

The softening of an organ, induced by inflammatory action, is frequently confined to one of the component tissues, especially to the cellular tissue ; the readiness with which the serous envelope may be stripped from off a parenchymatous organ, depends more upon the subserous cellular tissue, than upon the other structures ; and, in like manner, the softness of a whole organ is often assignable, rather to the deficient tenacity of the membrane which unites its lobules, than of the proper tissue.

Softening may be produced by causes totally differing from those produced by inflammation ; it may depend upon a deficiency or perverted state of the blood, and an anæmic state of the general system. For instance, in white softening of the brain, the arteries, which ought to have sufficiently nourished the affected parts, fail to do so on account of their being blocked up, more or less, by abnormal deposits. In certain softened states of the spleen, the blood contained in its parenchyma loses its consistence, and becomes more fluid than natural, from a perverted state of its constitution ; and the flabby muscles and general loss of tone of anæmic subjects are notorious.

In scrofula, the perverted state of the general nutrition produces softening of peculiar tissues, for instance, of the bones ; and in the cancerous cachexia like effects occur.

Long continued functional inactivity, for instance of the muscles of an extremity stricken with paralysis, tends to produce softening ; and pressure, in certain instances so interferes with the nutrition of a part as to diminish its cohesion. Fatty deposit in the ultimate cells

of tissues and organs, renders them soft and flabby; as will also infiltrations of certain morbid adventitious products. The compound granule cells found in acute softening of the brain, and mixed with pus in other situations, are described in the article on ADVENTITIOUS PRODUCTS. Softening may be accompanied by atrophy, or by hypertrophy, which is generally produced by simple congestion; or no alteration of bulk may occur. Three degrees of softening are recognised: — in the first, the softened tissue is still solid, but it breaks down and tears and can be perforated with ease; in the second, all solidity is gone, nothing but a pultaceous semi-fluid mass is found; and, in the third degree, the tissue is broken down and diffluent.

Softened parts may retain their natural colour, or may be paler, or may have an increase of colour. Softening, without any change of tint, occurs in mucous and serous membranes, in the brain, heart, liver, and uterus. All post mortem softenings are of this kind, except where the colouring matter of the blood has tinted the effused fluids.

In certain softenings of the brain the affected parts are much paler than usual, being of a dead white colour; there is a diminution in the quantity of blood usually present in the diseased parts; a like decrease of colour is found in other softenings.

Generally, however, softening is accompanied by reddening, or by an increased colour; the tints may vary from a bright vermilion to a brownish red, and may be seen as grey, almost black, and, occasionally, are yellow. These varieties of colour depend upon the amount of blood usually existing in the softened tissue, and upon the degree of congestion. The redness of softened tissues is occasionally partial, and merges into lighter tints as the tissue becomes harder. Partial effusions of blood, or highly injected vessels, are commonly found in red softenings.

Induration, generally speaking, is to be regarded as a symptom of previous or coexisting diseased states; its physical condition varies much in its nature, in the same or in different tissues, as proved by microscopical, mechanical, and chemical analysis; and both observation and experiment tend to prove, that it is produced by causes of a very opposite kind.

Changes in the amount of fluid destined for the nutrition of a part, frequently give rise to induration; an increased quantity of blood and a consequent increased deposit of solid structure, produce simple induration of many organs, which are liable to variations in the quantity of blood they may contain, for instance, the brain and spinal marrow, the cellular and muscular tissues; also of denser structures, as bone, in which the induration is occasionally extreme, and in fibrous tissues; they produce also hardening of the lymphatic glands and of the salivary glands. The brain has been found to be increased to twice its natural density and consistence. Muscular, fibrous, and cellular tissues, become so hard, as to give out a grating sound when cut; and the walls of some hollow organs, naturally soft and flaccid, acquire such a degree of firmness, that they preserve, when empty, a globular or cylindrical form, and spring up with considerable force after sudden pressure; and parts of bone acquire that degree of hardness, which has been termed eburneoid induration. An increased quantity of the usual fluids of nutrition frequently gives rise to induration, differing from that just described, in not being attended by deposition of solids. The accumulation of blood in the vessels of the lungs and spleen, the result of congestion, produces, sometimes, a great degree of hardness and density of these organs. Diminution of the quantity of the same fluid, especially when there is also a compressing force, is also followed by an increase of consistence, and, generally, by a decrease in bulk of certain organs; in pleurisy, for instance, dense false membranes, by their pressure, compress the lung into a small space, and its tissue becomes indurated from simple approximation; for, on the removal of the compressing agents, the lung can be inflated.

The inordinate increase and accumulation of the secretion of certain organs, as the mamma, testis, gall bladder, and kidney, produce a degree of hardness, sometimes equal to that of dense tumors, arising from the incompressibility of the fluids themselves, and the state of condensation of the walls of the organs in which they are accumulated.

Effusions of serum and blood into the tissues from mechanical causes produce great distension and induration; such is the case in the œdema of the cellular tissue of the extremities in dropsy; effusion of serum into the intermuscular cellular tissue produces hardening. Pulmonary apoplexy and ecchymosis in various organs, from a mechanical impediment to the return of blood to the heart, have a like effect.

But inflammation of a sub-acute form is the great cause of induration, from the effusion of serum and coagulable lymph; the former of which is absorbed, and the latter becomes "induration matter," whose properties are described under the head of ADVENTITIOUS PRODUCTS; this last product produces induration on account of its being actually denser than the tissues into which it is effused, and, also, by its compressing power, for it has the peculiarity of contracting and becoming hard after its deposition. Certain morbid states of the blood, occasionally produce indurations of certain organs.

The changes of form, with which induration may be connected, are numerous; none may, however, occur; the bulk also of indurated structures varies; it may remain unchanged, but, generally, it is increased, and more rarely, decreased.

The colour of indurated parts, is generally different from the normal tint; sometimes, owing to diminished vascularity, and to the presence of induration matter, it may be pale; at others, owing to increased vascularity, and

the state of the fluids of the tissue, and the presence of effused or infiltrated matters, it may be bright or dark red, grey, yellow, and sometimes almost black.

Induration presents several degrees of resistance to pressure or to the knife; much depends on the ordinary cohesion of the affected organ. Generally speaking, the first degree is characterised by a slight increase in the resistance to pressure; the second finds the tissue denser, cutting with a cracking noise; and the third comprehends increased cohesion, amounting to a cartilaginous or bony hardness.

Softening of the brain may be ascribed to inflammatory action, or to a defective state of the circulating apparatus of the organ; it may be an effect of a defective or perverted state of the body generally, and it is frequently caused by post mortem agencies. Now these four varieties of softening, although, as regards their external appearances they have much in common, differ considerably from each other, each having peculiar attributes. The first and second varieties are generally found in the most, and the third in the least, vascular parts of the brain. Post mortem softening occurs, for the most part, in the immediate neighbourhood of the ventricles, is usually very diffused, is found on both sides at once, and is, of course, never preceded by symptoms.

Softening of the brain may be partial or general, and may present various degrees: the least change of consistence is only to be recognised by the microscope; in a more advanced degree the softening is obvious to the unassisted senses, at first to the touch and then to the eye, the diseased part being pultaceous, and readily removed by a stream of water, a cavity surrounded by healthy structure being made evident.

In a more advanced degree still, the cerebral substance instead of being pultaceous is quite diffluent, and occasionally a perfect solution of continuity is found. The softened portion of brain presents various alterations of colour. In inflammatory softening, the colour mainly depends upon the previous quantity of blood in the part; it may be of a deep red colour, with or without effused clots of blood, and frequently merges at the edges into at first a deep, and then a pale, yellow colour. Sometimes the yellow colour is central and the reddened portion external, resembling a collection of pus, so much so that Lallemand described it as such.

A dull red ochre colour with more or less hardening in the neighbouring structure, is indicative of chronic disease of long standing; as is also a chalky milk appearance, and a bright vermilion, of a recent effusion of blood into a previously softened part. In commencing softening, a diffused blush, with or without spots of blood, is generally found. A deep grey colour and fawn and dirty white tints accompany inflammatory softening, but much more frequently that which is produced by a deficient supply of blood.

No alteration of colour takes place in post-mortem softening.

These distinctions of colour indicate no essential differences, as far as structure is concerned, for all coloured softenings may present the same histological characters. As a general rule, the red varieties are indicative of acute inflammation, yellow of subacute, and white or grey of deficient nutrition of the affected part; but this rule is by no means invariable.

Universal softening of the brain, accompanied by a smell of sulphuretted hydrogen, is found in children suffering from general debility, and occasionally in infants stricken with induration of the subcutaneous cellular tissue.

Softening from a defective state of the circulatory apparatus is found, for the most part, in persons advanced in life, and constitutes what is termed *white softening*. It depends on the presence of osseous, cartilaginous, or atheromatous matter in the walls of the arteries, nearly or quite blocking up their entire caliber, and affecting vessels of all sizes. It may supervene upon occlusion of the common carotid from ligature, and, indeed, upon any circumstance retarding or diminishing the quantity of blood to the brain; intense inflammation may disorganise the vessels, carrying blood to a remote portion of the brain, and thus cause softening; or a severe blow, or the presence of a tumor of greater or less density and magnitude, may act in the same manner.

The very fact of adventitious products being found within the arteries, hints at a perverted state of the brain and system generally; absorption does not progress in the diseased portions of the brain, which, having lost their supply of blood, are in a state analogous to that of an extremity attacked with gangrena senilis.

The softening of the brain which is produced by post mortem agencies is of very frequent occurrence. It may exist alone, or may complicate the other varieties, and is caused by the decomposition natural to organised bodies after death, or by the infiltrating action of fluids, which, either during life or in the agony of death, were effused into the ventricular cavities, and sub-arachnoid spaces.

Softening of the spinal cord is of not uncommon occurrence. It presents the same characters as those pertaining to the like affection of the brain, is produced by the same causes, and offers the same pathological characters. Softening of the whole cord may occur, but most frequently parts of it only are affected; it is found softened most frequently in the lumbar region, and not unfrequently in the cervical.

Induration of the brain may be general or partial, and presents three degrees of consistence. In its first degree, the affected part is nearly of the consistence of a brain which has been left some time in dilute nitric acid; in the second degree, the indurated part is of a cheesy, and in the third of a waxy, fibro-

cartilaginous hardness. General induration affects either the whole or the greater part of the brain: the degree of hardness never exceeds the first variety. The induration is not always equal throughout the whole of the parts affected, the central medullary parts usually exhibiting a higher degree of it than the grey substance. A section of the indurated portions generally presents increased vascularity, in the usual speckled and striated form; yet the reverse is occasionally observed, the brain being preternaturally white.

Induration of the spinal cord may be general or partial. Billard found a spinal cord in a child of a few days' old, which, without the membranes, supported a pound weight. In partial induration, the white, and not the grey, matter is usually affected. For further remarks on the softening and induration of the spinal cord, see the article NERVOUS CENTRES (Abnormal Anatomy).

Softening of the heart occurs as a diminished state of the cohesion of the muscular structure. It is a rare disease, and is produced by very opposite causes; from inflammation, from a defective state of the nutrition of the organ, with or without general anæmia, and from a perverted state of the nutrition of the muscular and cellular elements. The heart when softened collapses on itself when empty, tears with the greatest facility, and breaks down with little pressure, the finger perforating its substance and penetrating into its cavities with great ease. Its colour varies, being sometimes deep red and violet, at others dirty white, and occasionally of a faint yellow hue. Softening of the heart may be general or partial, superficial or deep-seated; it may be confined to the walls of a particular cavity, or to the ventricular septum, or it may occur in small patches, disseminated in the midst of the muscular substance. Softening of the heart may coincide with hypertrophy of its walls, or a dilated state of its cavities, and Hope found it in a case of angina pectoris.

When found as a sequel of carditis, the softening is of a dark tint, the fibres are dark from the whole heart being gorged with venous blood, soft and loose in their texture, being easily separable, and compressed with facility between the fingers. When accompanying chronic carditis and co-existing pericarditis, the white colour predominates, sometimes being nearly superficial, and attended by pericardial and sub-pericardial effusion.

The yellow-coloured softening is found in cases of local and general anæmia, in malignant fevers; and it sometimes has an inflammatory, as well as merely cachectic origin. An abnormal deposition of adipose tissue in the cellular structure of the heart, produces softening by affecting the nutrition of the muscular fibres, which suffer also from the state of system peculiarised by the above deposition.

Induration of the heart is said to follow carditis, and appears to be produced by the effusion of lymph into the cellular tissue, around the muscular fibres and beneath the serous membranes; by its contraction and subsequent hardening, it may pass into a substance almost equal to bone in hardness.

It may exist in any part of the organ, the whole of the apex and the columnæ carneæ of the left ventricle were found indurated in one case, and in another the walls of the ventricles were tough, did not collapse, and emitted on being struck, a ringing hollow sound. We sometimes find partial softenings and indurations in the same heart.

Softening of the lungs generally depends upon the presence of effused products of inflammation; for instance, in the engorged, hepatised, and suppurative stages of acute pneumonia. It is worthy of remark, that, although in the hepatised stage the lungs are heavier, contain less air, and appear denser, still they are more fragile, and on being pressed by the finger break down. The more acute and recent the inflammation, the greater the softening. When we press a healthy lung with the finger, it gives to the touch on account of the elastic state of the tissue; but this is lost, and an unusual resistance, easily broken through, is produced by the loss of air, and the presence of lymph, compound granule cells, serum, and an abnormal quantity of blood.

In the third stage of pneumonia, softening is produced by the alterations in the effused products; lymph, for instance, is converted into a yellow friable matter, which subsequently becomes pus. In typhoid pneumonia the softening is great, even in the first or congestive stage.

Softening of the lung may be produced by an insufficient supply of blood. A part of a lobe may be so indurated, that the vessels and bronchial tubes passing through it become blocked up; the tissue which ought to have been supplied by these becomes at first soft, and finally gangrenous.

Induration may occur in any part of the lung, it may affect simply the bronchi and the tissue in their immediate neighbourhood, or the interlobular cellular tissue and the parenchyma may suffer.

The bronchi after long continued and repeated attacks of inflammation are found in a more or less indurated state, the hardening being generally in the outer cellular coat, and the cartilages of the larger tubes may become as hard as bone. The lung in the vicinity is generally denser than it should be.

The interlobular cellular tissue may be hardened at the same time as the lobules, or separately; it becomes more apparent than usual, and acquires a density occasionally resembling fibro-cartilage, and sometimes exercises so compressing an influence on the lobules, as to obliterate them.

But it is as a sequel of inflammatory action of long duration, that hardening of the whole or part of a lobe is found; the vesicular structure first suffers, the air vesicles are obliterated, and, often enough, the bronchi and blood-vessels of a certain magnitude.

Such portions of lung are dense, not at all friable, possess a peculiar crispness, and contain little or no air.

The colour of an indurated lung may be light or dark grey, or brown, and rarely pale.

A section of a piece of indurated lung shows the circular apertures of the bronchi and larger blood-vessels, surrounded by a dense tissue in which no vesicular structure is seen. The fibrinous dense lymph which produces these changes frequently becomes the nidus for tubercular deposit.

Partial indurations are found around tubercular cavities and abscesses, and around collections of miliary, or of larger tubercular masses.

In certain obstructive diseases of the heart the circulation in the lungs is so impeded, that effusion of blood, constituting pulmonary apoplexy, or effusion of lymph, producing general increase of density of the whole lung, may occur.

Long continued pressure by a pleuritic effusion, has the effect of rendering the lung nearly solid and impervious to air.

In treating of alterations in the cohesion of *mucous*, *serous*, and *articular membranes*, it is necessary to premise that they consist of a basement membrane sustaining epithelium cells and supported by sub-basement areolar tissue in which vessels, nerves, and absorbents, are found.

The nutrition of the basement membrane and the proper development of the epithelium cells depend upon the amount and health of the fluid parts of the blood supplied to them by the capillaries of the sub-basement tissue. It is evident that any morbid state of this tissue will influence the integrity of the basement membrane and the epithelium cells; and it is known that, for the most part, physical alterations of these last depend upon such morbid states, and that these changes are most likely to happen where the cellular structure is loose and considerable in amount.

Softening has been found in all serous and fibro-serous membranes, and may be produced by inflammatory action and by a defective and perverted state of the general nutrition of the body.

The *lining membrane of the heart* is frequently softened, being at the same time redder and more vascular than usual. It is occasionally so soft as to peel very readily from the muscular structure; a like state of the *pericardium* exists with effusion of pus into its cavity. Softening of the *internal membrane of the venous system* is found of either a deep red or pale colour; the tissue is very lacerable and breaks down into a pulp under the scalpel; it may be caused by phlebitis, by the pressure of a considerable column of blood, especially when the valves have been obliterated; and is found in cases of malignant fever, scurvy, and whenever the fluids are greatly altered. Post mortem softening is frequent enough to raise our suspicions, and great allowance must be made for the macerating and colouring properties of the blood.

Chronic softening of the *internal membrane of arteries* is occasionally found; when so affected the serous tissue is easily lacerable, and such solutions of continuity are determined by causes, which ought in health to have no influence. Portions of the interior lining membrane may be found retracted and rolled up within the canal, so that with the effusion of lymph which generally occurs at the same time, and the consequent coagulation of a small portion of blood, the artery may become completely obstructed and obliterated in a part of its course. Occasionally, the arteries of the upper and lower extremities become thus affected in succession, on the employment of the slightest exertion, indicating a very extensive affection of the nutrition of the arterial system. We find, in cases of anæmia, and where atheroma is being deposited, considerable diminution of the general tenacity of the large vessels.

Softening of the *arachnoid*, *peritoneum*, and *pleura* is generally found where there is effusion of pus, or blood into the sub-basement tissue; it rarely occurs when lymph is thrown out into the serous cavity, but seems to be a more advanced phenomenon of inflammation, or, rather, is produced by inflammation of a more intense and destructive character.

Dalmas ascribes nearly all serous softenings to diseased states of the subserous cellular tissue, and we find constantly that on account of the altered state of this cellular structure, the peritoneum and pleura may be stripped off large spaces of the parts they cover; it is notorious, that in the pelvis sero-sanguineous effusion into the subserous cellular tissue, and consequent lacerability of the serous membrane, frequently occur. Pulpy degeneration of synovial membrane is a kind of softening with a perverted state of the nutrition of the tissue.

Softening of mucous membranes is generally produced by inflammatory causes: it is most frequently noticed, and is best studied, in the alimentary canal, part or the whole of which may be affected; it is most frequently observed at the end of the ilium, in the depending portion of the colon, and in the cæcum; in the right and left hypochondriac regions, and in the sigmoid flexure.

Softening of the mucous membrane in general, or of any one or more of its elements in particular, presents various degrees. In the first degree, the mucous membrane, instead of possessing that degree of cohesion which permits of its being detached from the submucous tissue, breaks as soon as it is seized between the fingers or blades of the forceps; in the second degree, the edge of a scalpel, or the finger, pressed lightly over its surface, converts it into a soft and somewhat opaque creamy looking pulp; and, in the third stage, it is so soft that it is removed with ease by a slight stream of water. In this stage portions of the mucous membrane are found partially or entirely destroyed, and having been removed by the fluid contents of the stomach or intestines, as the case may be, during life, the submucous cellular tissue is thus found destitute

of its natural covering. It is in this manner that various forms of softening are produced, as irregular or circular patches of various sizes. It is important to notice this circumstance, for, when the softening is limited to the glandulæ solitariæ, as is frequently the case in dysentery, it might be overlooked; these bodies being very small, and their entire destruction by softening being often unaccompanied by any obvious alteration of the mucous membrane itself, the seat and nature of the intestinal affection might not be ascertained, were it not for the presence of a number of minute circular patches, which, when narrowly examined, are found to be the result of softening of these follicles; for it often happens that enlarged follicles are seen intermixed with the patches, and which, when a scalpel is carried over the surface of the mucous membrane, break down or are removed, and thus other patches are formed similar to the former. These circular patches, which have the submucous tissue for their base, are often described as ulceration of the mucous membrane; but in all cases of doubt, the scalpel, used as above, will enable us to determine their nature.

Softening of the mucous membrane in the form of stripes and bands, has been described with great care by Louis, and has been much insisted upon as a characteristic of inflammatory softening; but Carswell has proved its origin from post mortem causes.

Softening of the mucous membrane of the digestive organs, may present various degrees of redness, or it may be quite pale; the redness may be confined to the softened part, or it may extend to the neighbouring parts at the same time; or the latter may be red and the former pale.

The redness of the softened membrane may vary from a light or a dark red to a brownish or purple; varieties of colour the value of which it is by no means easy to estimate, inasmuch as the quantity of blood in an inflamed tissue cannot be taken as a measure of the degree of inflammation which had caused the accumulation of this fluid.

The pale softening presents also some variety of tint. The softened tissue is either of a pale greyish or yellowish grey tint, being little altered from its natural colour; or it may be paler than natural, when it generally presents a milky aspect, owing to the colour of the submucous tissue being seen through it.

The pale softening is found in pthisis, in tubercular disease of the mesenteric glands, and in any disease accompanied by great emaciation.

Softening may be accompanied by thickening of the submucous tissues, and may precede and surround ulcerations.

The inflammatory softening of the other mucous membranes resembles as closely as possible that which has been described; it is not however so frequently complicated with post mortem effects, nor does it so often occur, except in the œsophagus, stomach, and intestines from the action of irritant poisons, which produce it either by their direct action, or by inducing and modifying inflammation.

Softening of mucous membranes from post mortem causes, is of great importance as a pathological fact, and may be produced by the action of the secretions of the membrane itself, or by putrefaction. This last cause is of doubtful efficacy; it is not likely to be met with in post mortem examinations, made at a reasonable period after death; it may however suffice to cause complete decomposition, when the membrane has been the seat of disease before death, and more particularly when the lesion has been of such a kind as to deprive the tissue of its vital properties suddenly. General putrefaction rapidly occurs in many cases of sudden death, especially in those in which the nervous system, or blood, or both, happen to be the vehicles of the destructive agent.

Softening from the action of special secretions may occur in two manners, either by simple maceration, which is long in taking place, or by chemical action. The first may happen in all mucous membranes, the second in the stomach and intestines alone.

Under favourable circumstances, and at a greater or less period after death, we find softening of the coats of the stomach, perforation, and the contents of the viscus free in the cavity of the peritoneum.

Various opinions have been given by the most celebrated pathologists, to account for this phenomenon; some embracing the views of Hunter, and recognising a chemical and post-mortem cause; and others attributing it to certain inflammatory causes, which produced ulceration and subsequent perforation.

Now, Hunter's view is demonstrable by direct experiment, whilst that held by the others is disproved by the absence of symptoms during life sufficient to account for such vast organic changes, and by the difference between such ulceration and those solutions of continuity which we are now about to describe.

The following facts tend to strengthen the first, and militate strongly against the latter opinion. When a rabbit, dog, cat, or any animal, in fact, is killed an hour or so after a meal when digestion is going on, and is allowed to remain in one position and in a moderate temperature, we find, after a few hours have elapsed, that the mucous membrane of the most depending part of the stomach is softened, and can, with the submucous cellular tissue and the muscular coat, be broken down with the greatest facility. The vessels ramifying in the softened part are black from the action of the solvent upon their blood.

After a greater lapse of time we find the peritoneum perforated, and the contents of the stomach in its cavity; by and by the tissues in the immediate neighbourhood of the stomach begin to suffer, and we see the abdominal muscles, and the cuticle covering them, eaten through by the gastric juice.

In fish, softening and perforation occur so

rapidly, that, unless perfectly fresh specimens be used, no microscopic structure can be distinguished in the stomachal mucous membrane. I have noticed the same thing to occur in caterpillars: their stomachs, which contain both globular and columnar cells, after a time become softened and are perforated, so, subsequently, is the external cuticle; nature seems to have taken this original method of doing away with useless organisms.

In ulceration of the stomach the affected part is generally circular, and if it reaches the peritoneum excites inflammation in the reflexion contiguous to it; by this means perforation is rarely accomplished. Now, in post mortem perforations the softened part, said by some to be the seat of ulceration, is diffuse and the perforation large and irregular, and no part of the neighbouring peritoneum presents the slightest trace of recent inflammation; shreds of muscular tissue and cellular membrane, moreover, form an irregular fringe around the opening, and, by their presence, detract greatly from the theory which calls such phenomena pathological and not pseudomorbid.

Generally speaking, the fundus is most frequently the part of the stomach most affected by the gastric juice; but every thing depends upon its being the most depending part, and upon its containing more or less semi-digested food.

The solvent matter is secreted by the tubes of the stomach, and consists of pepsin in combination with lactic acid and water: it possesses the power of disintegrating all dead structures, but cannot influence the living tissues. It is not secreted when the stomach is empty, a stimulus to the mucous coat, in the form of some matter foreign to the stomach, is necessary for its production; it is probably the case, that an ulcer of the mucous membrane may act as a stimulus, and that a certain quantity of juice may always be present in the stomach; and that when, by the depressing effect of this lesion, the general nutrition suffers and the tissues are less able to resist decomposition, the gastric juice may act locally on the surface of the ulcer, and produce perforation before any peritoneal adhesion is formed. Perforation of the coats of the stomach sometimes occurs suddenly after a meal; it is produced generally by the giving way of some small ulcer, the progress of which had been enhanced by the presence of a large quantity of corroding liquid.

Post mortem softening may modify and exaggerate softening from other causes, and differs in its own appearances under various circumstances. The colour which the softened membrane presents appears to depend upon the quantity of blood contained in the organ at the time of death; if the quantity be small and natural, the softened parts are of a dull yellow or orange tint; and this colour increases with the quantity of the blood, and is accompanied by a black colour of the vessels. In infants and young children, and in anæmic patients and persons whose blood is deficient in quantity and altered in quality, containing a great disproportion of serum, the whole stomach appears as if macerated; it is, indeed, sometimes infiltrated with serosity, and is so completely deprived of blood that no trace of this fluid is perceived except in some of the larger veins.

Post mortem softening and perforation of the intestines may occur from the presence of an acid fluid, either within them or without, and derived from the stomach; in the one case, softening is from within outwards, and, in the other, from without inwards.

Softening of the skin: the skin may be softened wholly, or one or more of its layers only. In some skin diseases, especially among scrofulous subjects, there is an alteration of the cohesion of the epidermis, which is properly formed by layers of cells, the row nearest the basement being smallest and more liquid than the others, the more distant being dry and united laterally, so as to form a dense integument. Certain defects in the quantity and quality of the fluid contained in the newest made cells prevent them from progressing, normally, in their development; they do not become dry, neither is any disposition evinced by the basement to secrete other cells; under these circumstances the epidermis is soft, and the basement tender and red, the tissue beneath being visible.

The cutis may lose its consistence in several manners. When considerable quantities of serum are collected in the subcuticular cellular tissue, the cutis becomes mechanically distended and remarkably soft; and sometimes is only represented by a thin friable tissue, which breaks down with the least pressure. It may gradually lose its fibrous structure and degenerate into a tissue analogous to that usually found beneath it.

Softening also occurs as a sequel of acute active local congestion.

The *appendages of the skin*, the nails, hairs, and, in the lower animals, horns, undergo softening to a certain extent in diseases of long standing, attended with great emaciation; and softening of the *cornea* with ulceration is a common symptom of starvation.

Induration of mucous membranes, is generally caused by long continued sub-acute inflammatory action; the sub-basement cellular tissue is generally affected, and thickening of the whole structure, with hypertrophy of the papillæ, where they exist, is found at the same time. Induration with hypertrophy is consequent upon chronic dysentery, and upon chronic inflammation of the bladder. Ulceration of mucous membrane is generally accompanied by surrounding thickening and induration, and this last is frequent in the gall-bladder, gall-ducts, uterus, and urethra. Induration of mucous membranes is generally accompanied by contraction of their caliber or surface, — from the consolidation and subsequent contraction of lymph effused into the cellular structure. Fatal stricture of the intestines is produced in this manner, and so

are urethral strictures. Ulceration of the stomach when healed, is followed by contraction of the cicatrix; and when the ulcer has extended into the duodenum from the stomach, pyloric constriction of the severest kind occurs. The colour of indurated mucous membrane is generally paler than natural: the opposite may occur, and the degree of density varies from a slight increase to a bony hardness.

An *indurated* and thickened state of the *membranes of the brain*, *pericardium*, and *pleura*, are found after long continued chronic inflammation, either of the membranes themselves, or of the parenchymatous structures in their vicinity. Effusion of lymph behind serous membranes always tends to their becoming harder and thicker than natural; after a while the lymph becomes organised and contracts, and produces a puckering and irregularity of the membranes. We find thickening and induration of the pleura over large tuberculous cavities, the peritoneum covering the liver, and intestinal canal, and in the sacs of old herniæ. Constriction of any part of the intestinal canal, and also of the pylorus, may be produced by sub-peritoneal effusion of lymph.

Softening of the liver usually occurs in a manner not to be appreciated by the eye, being simply easily broken down under the finger; occasionally, however, the liver looks as if it had been macerated for a great length of time in a dark fluid, its texture has completely lost its cohesion, and has become in certain spots quite diffluent. Livers in a state of softening may retain their ordinary colour, or it may be increased, and even decreased, in an extraordinary manner; for, sometimes, no traces of blood can be found, except in the larger venous trunks, and the tissue of the liver is pale and light drab in colour. Softening of the liver is found frequently on the anterior and convex surface, as a product of inflammation; partial and curable softening has been noticed to accompany inflammation of the right lung; and, finally, the consistence of the liver is much influenced by the abnormal deposition of fat, which sometimes occurs in the ultimate cells of the organ.

Induration of the liver is generally produced by the deposition of lymph, its subsequent contraction and its compressing influence upon the lobules. This effusion is the consequence of adhesive inflammation in the areolar tissue about the twigs of the portal vein, serum and coagulable lymph are poured out, the first is absorbed, and the latter consolidated, and ultimately converted into dense fibrous tissue, which divides the lobular structure of the liver into well defined masses, gives great density and toughness to the organ, by compressing the small twigs of the portal vein, and the small bile ducts, thus impeding the flow of blood and the escape of bile, and causing the usual yellow tint which accompanies this disease.

This deposition of fibrous tissue produces different effects according to the parts it principally involves. Sometimes the lymph is effused exclusively into the cellular tissue of the portal canals of considerable size, and if the person die some time after this has occurred, all the considerable branches of the portal vein are found surrounded, in some places, to the distance of half an inch, by new fibrous tissue, which by its contraction has drawn in and puckered the adjacent portions of the liver. The remaining portions of the liver may be little or not at all altered in texture, and may be readily scraped away from these indurated portions; the main branches of the portal vein are still pervious, but many of the small branches leading from them are obliterated, the parts which they supply atrophied, and the liver correspondingly diminished in bulk. When such portions are near the surface, the capsule is drawn in, thickened and puckered, and generally covered with false membranes.

In other cases, the fibrous tissue is not found around the larger veins, but in the vicinity of the small twigs that separate the lobules; all the substance of the liver is thus rendered tough; and when the organ is sliced, the fibrous tissue is seen to form distinct lines, between small irregular masses of lobules. At the parts on the surface of the liver which correspond to these lines, the capsule is drawn in, so that the organ presents what is termed a hobnailed appearance. The degree of hardness is determined by the amount of the adventitious tissue, and, as a general rule, the denser the organ, the paler its colour; ordinarily, the colour is pale grey, or resembles that of impure wax; and hence the term *Cirrhosis*.

Induration of the liver occurs around growths, abscesses, and hydatid cysts, and may be produced by inflammatory action of a specific or non-specific nature.

Softening of the spleen is produced by an altered state of the fluid which it contains naturally, and by inflammatory action, or by both causes. Softening produced by the first means is common in low fever, intermittents, and scurvy; the fibrous element of the spleen does not suffer; but the blood, which is contained within its meshes, loses its natural consistence, appears to lose its coagulating power, becomes dark, and is washed away, leaving the white fibres intact, by a slight stream of water. In softening from inflammatory action the whole tissue of the spleen is disorganized; it breaks down under the slightest pressure; the external fibrous envelope is much softer than usual; and its internal prolongation is totally destroyed. Both of these kinds of softening occur, with or without alteration, in the bulk and dimensions of the organ.

Induration of the spleen may also arise from an abnormal state of the blood, and from inflammatory action. When the consistence of the blood is altered, the spleen, which may or may not be enlarged, cuts like liver or frozen muscle; and no great quantity of blood follows the incision, the whole tissue being, in fact, denser than usual.

Inflammatory hardening may or may not be

equal in degree throughout the whole organ; frequently, certain spots, the seat of old effusions of blood, are denser than the indurated tissue around them; and eccymoses and dark yellow and black spots, are found sometimes scattered over the hardened tissue. This variety of induration may be accompanied by increase or decrease of bulk, or no alteration in size may occur; in degree, it may vary from the slightest increase of consistence, depending upon excessive nutrition, to a bony hardness.

Softening of the kidney is of common occurrence, being frequently found, with an enlarged state of the organ, in several of the diseases comprehended under the term Bright's disease. It exists also in the kidneys of diabetic subjects, and in some cases of renal calculi. When produced by inflammatory action, the softened kidney is dark red, and when a consequence of a perverted state of the nutrition of the organ, it is usually of a pale colour. Generally speaking, the softened state is produced by enlargement of the uriniferous tubes, and a consequent diminution of the solid matrix, or this last only may be affected; and when such is the case, the tissue breaks down with the slightest pressure. In degree, softening may vary from simple flabbiness to a state approaching diffluence.

Induration of the kidney is generally found with an atrophied state of the organ; it is a sequel of acute, and is found in chronic, nephritis, especially in gouty subjects. In these the kidney is frequently indurated, paler than natural, less vascular, and many of its tubes may be blocked up with urate of soda. Induration is sometimes accompanied by an hypertrophied and a darkened state of the organ. In the first stage of induration, the consistence of the organ is slightly exaggerated, and the finger makes no impression on it; in such kidneys we find superficial star-like venous twigs, and more or less confusion of the cortical tissue. In a more advanced stage, the tissue may become nearly as hard as cartilage, and perfectly colourless. Portions only of the kidney may be affected, but, generally, the greater part of it suffers; and it is, comparatively speaking, rare to find cartilaginous induration of one or more of the mammilated processes.

Induration and softening of the uterus are frequently products of acute inflammation of the organ; the first is formed but slowly, the latter with great rapidity, and may or may not be complicated with effusion and infiltration of pus, into the muscular structure. Uncomplicated softening is frequently the result of a more chronic and subacute inflammatory action, and is occasionally found in the impregnated uterus, being made known to the practitioner by the spontaneous rupture of its walls, and the passage of its contents into the cavity of the abdomen. A softening, either general or partial, is found in cases where there were no uterine symptoms during life; the tissue is as friable as that of a softened spleen; but none of the products of inflammation are to be found. It is, probably, produced by a perverted and defective state of the general nutrition; the uterus, from its low vitality, prominently suffering. A putrid sloughy-looking softening occurs around growths and ulcerations of the uterine tissue.

Softening and induration of the ovaries are usually produced by acute or chronic inflammatory action: the one, if found in the early stages of ovaritis, is produced by the effusion of serum into the tissue of the ovary; and the other, a sequel of the same disease, is produced by the contraction and hardening of effused lymph.

In old age, thickening of the fibrous coat, and atrophy, and induration of the stroma, with special hardening around old Graafian vesicles, are very common: this state is frequently preceded by a flabby consistence of the organ.

In the puerperal state, the ovaries are subject to complete softening and disorganization; the natural structure is lost, and, in its place, is a pulpy diffluent bloody-looking mass.

An indurated state of the *prostate gland* is common enough in old age, and is generally accompanied by hypertrophy; and a grey or white hardening of the *testicle* and *epididymis*, with or without destruction of the seminiferous tubes, is frequently found as a sequel of chronic inflammation.

A softened state of the whole or part of the *osseous framework* of the body, is met with in scrofulous habits, and in persons suffering from cancerous cachexia, under the form of rachitis and mollities ossium. In the first of these diseases, there is a deficient deposit of earthy matter, and the animal matter is probably of an unhealthy quality; whilst in the second, the constituents are not deficient in quantity, but bad in quality, and the vital properties of the bone are completely deranged; the osseous structure has lost its cohesive power, and breaks with the least muscular effort. In rachitis, the bones may be bent in any direction, and are easily cut; their centre resembling cartilage. In mollities ossium, the knife penetrates the tissue, which appears to consist of numerous cells, with thin walls, and containing an oleaginous fluid, with the greatest ease. Occasionally, bones are found so softened as to resemble lard in consistence; and sometimes in subjects which have suffered from chronic disease, the ribs are more easily cut through than the cartilages. In caries, also, there is a softening and absorption of the bony texture, which crumbles away on the slightest touch.

Softening of cartilage is found under three forms. It may lose its usual elasticity and become doughy, or the usually dry and elastic cartilage of an adult may be found soft, as if it were that of an infant; it acquires extensibility, and its elasticity diminishes. Finally, the cartilage of adult life may so lose its consistence, as to resemble embryonic cartilage; it becomes pale and transparent, its quantity

of solid matter being very small, and its proportion of water great, and the softness considerable.

Fibrous tissue resembles cartilage in its alterations of cohesion, and both are apt to become indurated by a deposit of osseous matter.

Softening of the muscular structures may occur, as a sequel of inflammation in the cellular tissue which surrounds and binds together the ultimate fibres ; or as a result of long continued inaction, produced by loss of nervous influence, as in paralysis, or by long standing disease. Softened muscles are pale, flabby, and contain much fat ; are incapable of long or severe action, and are deficient in irritability.

Softening of the muscles of organic life, generally depends upon an inflammatory condition of their neighbouring submucous or subserous cellular tissue.

Softening of cellular tissue is very common. It has already been noticed as occurring from effusion of serum, pus, and blood. These render it more palpable and more liable to be torn, and its simple lacerability is frequently set down to softening: it is difficult, however, to draw the line. A great consequence of softening of the cellular tissue, is softening of the subjacent and neighbouring tissues; we have noticed this to a considerable extent in softening of the sub-pleural tissue, and also of the submucous and subperitoneal tissue of the alimentary canal.

There is hardly any part of the body in which cellular tissue is not to be found ; and consequently nearly all the tissues may be influenced by its softened state. The effusion of fluids into the areolæ of the cellular tissue, may follow inflammatory action or may be produced from a malignant or typhoid state of system, and from post mortem causes.

The colour of the softened membrane depends upon the nature of the effused fluid.

Induration of cellular tissue is generally caused by the effusion, and subsequent contraction and hardening of coagulable lymph ; or the simple effusion may produce hardening, as in the immediate vicinity of old ulcers. However, it is notorious that even in this case contraction and consolidation occur at a little distance from the seat of irritation ; in certain skin diseases, and in the cicatrices following burns, great injury may be effected by the contracting power of the effused lymph.

But it is behind mucous and serous, or sero-fibrous membranes, that induration from inflammatory action principally occurs, and leads to effects, most noxious to the general economy ; strictures of the gullet, pylorus, intestines, and urethra, depend upon the submucous or subserous effusion and consolidation of lymph.

A hardened state of the mammary gland depends upon the same cause. Dense, crisp-cutting consolidations of cellular tissue, are frequently mistaken for scirrhus, and, indeed, are frequently the seat of morbid growths.

Induration of the cellular tissue may depend upon a perverted state of the general nutrition ; in syphilis, for example, there is frequently subperiosteal effusion of lymph, which has a tendency to ossify. It is also very frequently brought about, and becomes cartilaginous in hardness, by long continued local irritation. We notice the indurated state of the tissue around scrofulous glands, and its condensed form around miliary tubercles. The disease, which has been termed hardening of the cellular tissue, occurs in infants. The subjects of this disease are, for the most part, feeble, sometimes imperfectly developed, and generally born before the full period. It is a disease seen, for the most part, in hospitals, and is found where filth, bad ventilation, and worse food abound ; consisting, in a wax-like hardness of the subcutaneous cellular tissue, and is produced by the effusion of a sero-albuminous fluid into its meshes. This effusion produces swelling of the affected parts, as well as hardening; and occurs, first of all, in the inferior extremities, passes from the feet upwards, and subsequently attacks the hands, arms, and then the trunk itself.

The hardened limbs are dry, cold, and may or may not pit on pressure ; their colour is either unchanged, or has a dull yellow or a lived hue. Symptoms of obstructed respiration supervene before death.

When a section of an affected limb is made, and the subcutaneous cellular tissue is well exposed, we find its cellular appearance much increased, from the interstices being filled with a fluid, which is either limpid, or more concrete, and of a citron colour, or tinged with blood. The quantity of this fluid determines the degree and amount of induration ; and occasionally the fatty structure beneath the skin is hardened from the compressing influence of the effusion.

It is very doubtful if the effused fluid becomes wholly concrete. Chevreul says, that the serum of the blood, in infants affected with hardening of the subcutaneous cellular tissue, contains a large quantity of a spontaneously coagulable matter, analogous to that which is effused into the affected tissue. Great and general venous congestion is always found in these cases, and would seem to depend on insufficient vital energy, produced by the depressing influences of damp, bad nourishment, and cold.

For some particulars respecting the Softening and Induration of " Growths," see article on ADVENTITIOUS PRODUCTS.

(*P. Martin Duncan.*)

SOLIPEDA. Syn. *Solidungula*, *Pachydermes Solipedes.* — An important group of herbivorous quadrupeds, regarded by Cuvier as constituting a third family of his order Pachydermata, and defined as " animaux à sabots non ruminans," or non-ruminant, ungulate quadrupeds. They form, however, a race of animals that presents many remarkable peculiarities of structure, and, from their great importance to mankind, demand, in a work like the present, a somewhat minute

description of their anatomy and general organisation.

The Solipeda, zoologically considered, comprehend but the single genus Equus, at once distinguishable from all other quadrupeds by the remarkable construction of the anterior and posterior extremities, each of the four feet appearing externally to consist of but a single toe enclosed in a solid hoof of horn, although, within, there are found concealed beneath the skin the rudiments of two other digits, appended to each side of the metacarpal and metatarsal portion of the limb.

The genus Equus is further characterised by the following peculiar disposition of the dental apparatus: — There are six sharp and trenchant incisors both in the upper and in the lower jaw, and an equal number of grinding teeth, the crowns of which are of a square form, each having its surface intersected by deep plates of enamel, arranged in the shape of four crescentic masses, in addition to which there exists in the teeth of the upper jaw a small disc of enamel, situated upon the inner border of each tooth.

The males have, moreover, two small canine teeth developed in the upper jaw, and sometimes in the lower one also; but these canine teeth, or *tushes* (tusks), as they are generally called, are for the most part altogether wanting in the females. A considerable interspace exists between the canine teeth and the first molar, so that that portion of the mouth of the horse which is opposite to the commissure of the lips is devoid of any dental armature, a circumstance of which man has availed himself for the purpose of introducing into the mouth of these animals that bit by the aid of which he is enabled to subjugate his steed, and thus secure to himself the services of an assistant not less conspicuous for his indomitable strength than for his matchless docility. The stomach of the Solipeds is simple in its form, and of moderate dimensions, but their intestinal canal is of very great length, and the cœcum and colon enormous in their proportionate size.

Thus characterised, the genus Equus is found to comprehend several different races of quadrupeds that are generally regarded by modern naturalists as constituting so many distinct species. These are — 1st. The Horse (*Equus Caballus*), "man's noble companion in the chase or on the battle-field, in the labours of agriculture, in the arts, or in commerce." The original country whence the horse has been disseminated through the whole world has now become a matter of uncertainty, although most probably the wide plains of eastern Europe and of Asia, where wild horses still abound, may be pointed out as their central station. That they were in common use in Egypt from the very earliest period of which we have any record, is evident from the sacred writings (*vide* Gen. c. xlvii. v. 17., and c. l. v. 9.), and hence it is supposed to have been derived by the Arabs, Persians, Ethiopians, Indians, Parthians, Scythians, &c. At the present day, wild horses are by no means common even in their native regions, owing to the encroachments of man upon their original haunts; but, on the other hand, they have spread over the vast prairies of the new continent, and may now be said to be as extensively distributed as the human race itself.

The second species admitted by zoologists to form a distinct race is the Dzigguetai (*Equus Hemionus*), intermediate in size between the horse and the ass, from both of which it is distinguished by its colour, which is light bay, with a black mane and dorsal line, and it also has a black tuft of hair at the end of its tail. This animal is found in large troops among the sandy plains of Central Asia.

3d. The ass (*Equus Asinus*), at once recognisable by the length of its ears, by the tuft of hair at the end of its tail, and by the black cross upon its shoulders, which is the first appearance of those transverse bands which become numerous in the succeeding species. This animal seems to be indigenous to the desert regions of Central Asia, where vast troops of them still abound in a wild state.

4th. The Zebra (*Equus Zebra*), a native of the southern regions of Africa, and conspicuous for its symmetry and the alternate transverse stripes of black and white with which its skin is all over marked.

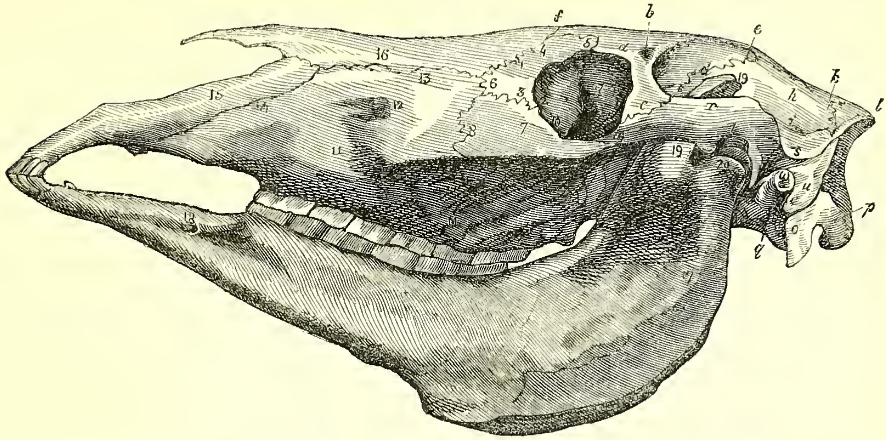
5th. The Quagga (*Equus Quaccha*), a native of the same regions as the Zebra, from which it principally differs in the colour of its skin and more horse-like appearance. Its hair upon the neck and shoulders is brown, marked transversely with white stripes; its croup is of a greyish-red colour, while the tail and legs are white. The name of this animal is derived from its peculiar voice, which somewhat resembles the bark of a dog.

6th, The Onagga, or Dauw (*Equus montanus*), is somewhat less than the ass, and in its shape resembles the quagga. Its general colour is a light bay marked with black stripes, that are alternately broader and narrower over the head, neck, and trunk; the hinder stripes are directed obliquely forward, while the legs and tail remain white.

With respect to their anatomy, it may be observed, that all the above species resemble each other as closely in their internal economy as they do in outward form, and accordingly, in the following pages, we shall confine ourselves principally to a description of the horse, as being the typical species of the group, noticing, however, incidentally, such peculiarities of structure as may be worthy of remark in the humbler congeners of their noble prototype. So near, indeed, is the relationship between the different members of the entire genus, that they will breed together without difficulty, although the progeny of such a union, the mule, is generally incapable of reproduction. Such is well known to be the case between the horse and the ass, as also with the zebra, and doubtless with the genus generally.

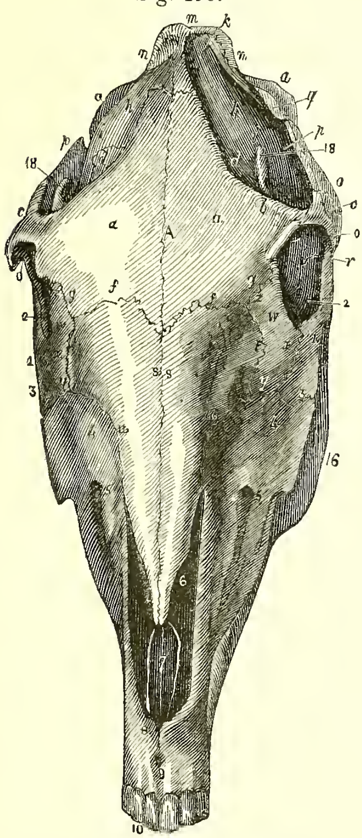
OSTEOLOGY.—*Skull.* The head of the horse is at once recognisable by the following characters*, namely, by the great enlargement between the orbits (*fig.* 496. *a a*), by its slightly

Fig. 495.



a, b, c, d, e, f, os frontis; *b,* supra-orbital foramen;—*h, i, k,* parietal bone;—*l, o, p, q,* occipital bone; *l,* occipital protuberance; *p,* condyle; *o,* paramastoid process; *q,* basilar portion;—*r, s, t, u, w, x,* temporal bone; *r,* zygomatic portion; *x,* suture with the malar bone; *t,* glenoid cavity; *u,* mastoid process; *w,* tympanic ring;—1, 2, 3, 4, 5, 6, lacrymal bone; 2, position of the nasal duct;—7, 8, 10, malar bone;—11, 11, 12, 13, 14, superior maxillary; 12, infra-orbital foramen;—15, intermaxillary;—16, nasal bone;—17, 18, 19, 19, 20, inferior maxillary; 18, mental foramen; 19, 19, coronoid process; 20, condyle.

Fig. 496.



A, a, a, b, c, c, d, d, f, f, g, g, frontal bones; *A,* frontal suture;—*h, h, i, i, k,* parietal bones;—*m, n, n,* occipital;—*o, o, o, p, q, r,* temporal bones; *o, o, o,* zygomatic processes; *r,* suture with the malar;—*s, s, t, u, u,* nasal bones;—*w, x, y, z,* lacrymal bone;—1, 1, 2, 2, 3, 3, malar bones;—4, 4, 5, 5, 6, superior maxillary bones; 5, 5, infra-orbital foramina; 6, palatal process;—7, 8, 9, intermaxillary bones; 8, nasal process; 7, palatal suture; 9, foramen in the suture; 10, incisor teeth;—16, 18, 18, inferior maxilla; 18, 18, summits of coronoid processes.

convex profile, by the length of the face, which is more than double that of the cranium, and by the vertical depth of the lower jaw, which is more than that of the whole cranial portion of the skull. The temporal ridges, prolonged backwards from the post orbital apophyses, extend as far as the middle of the parietal bones, and there form a short sagittal crest upon the mesial line of the skull, whence, proceeding backwards, they diverge and extend as far as the occipital ridge, which is truncated above (as is the case in the pachydermata generally), and projects over the posterior surface of the occiput. The intermaxillaries are prolonged considerably beyond the nasal bones, which last, by their points, arch over the cavity of the nostrils to a considerable extent. The temporal arch is comparatively very short, nearly straight, and is situated entirely in the posterior third of the skull.

As regards the individual bones of the skull, it may be observed that the two *frontals* (*fig.* 496. *a, a, f, g*) remain distinct from each other after the parietals become consolidated into one piece; they are of remarkable breadth between the orbits, and posteriorly penetrate to a considerable depth between the parietal bones. The *ossa parietalia* (*fig.* 495. *h, i*) give off on each side of the cranium a pointed

* Cuvier, Ossemens fossiles, t. ii. p. 108.

process, which encroaches largely upon the squamous process of the temporal bone. The zygomatic process of the temporal (*fig.* 496. *o*) has at its base a process which projects upwards and backwards. This process constitutes the entire length of the temporal arch, articulating anteriorly by suture with the post-orbital process of the os frontis (*fig.* 495. *b*, *c*), which is very long: the zygomatic process of the temporal even extends to beneath the orbit, the bony circle around which it contributes to form, and is thence prolonged behind the *os malæ*, so as to become articulated with the superior maxillary bone. The occipital suture is situated considerably in front of the superior occipital ridge; nevertheless there is generally an interparietal bone of quadrangular shape, called by hippotomists the *os quadratum*, but which at an early age becomes consolidated with the two parietals. The interparietal is, indeed, itself frequently divided into two pieces in the new-born foal. It is always much too narrow to reach as far as the temporals.

The anterior sphenoid appears but very slightly in the orbit. The posterior sphenoid mounts upwards in that region almost as high as the temporal, but without coming in contact with the parietal. Inferiorly, it is prolonged in a square form considerably beyond the pterygoid region. The glenoid cavity for the articulation of the lower jaw is situated beneath the middle of the temporal arch; it is convex inferiorly, and has a tubercle situated behind its internal extremity, behind which, and on the same level, is situated the *meatus auditorius externus*. The bony meatus remains distinct from the temporal even when it has become completely consolidated with the tympanic and petrous portions of that bone. The tympanum is but little prominent, and of a very irregular shape. The petrous portion appears externally at the side of the occiput (*fig.* 495. *u*), in front of the base of the para-mastoid apophysis (*fig.* 495. *p*), which is here long and pointed.

Of the bones of the face it may be observed, that the ascending apophyses of the intermaxillary bones (*fig.* 495. 15) are placed very obliquely, and become connected with the ossa nasi at about one third of the length of those bones from their anterior extremity. Inferiorly, their palatine apophyses penetrate between the maxillary bones as far as the first molar teeth, leaving two incisive foramina, or rather fissures, which are about half the length of the apophyses themselves. The pointed extremities of the ossa nasi arch over the cavity of the nose nearly as far as the middle of the intermaxillary bones. Superiorly, the ossa nasi increase in breadth as far as the inner angles of the orbits, where they become joined with the lacrymals (3, 4, 5, 6), which descend to a considerable distance upon the cheek, and enter almost as largely into the structure of the orbital cavity. The *jugal* (*fig.* 495. 7, 8) advances upon the cheek as far forwards as the lacrymal bone, and terminates beneath the middle of the orbit. This bone does not extend sufficiently far backwards to enter into the composition of the zygomatic arch, properly so called. It forms upon the side of the cheek, by its union with the maxillary bone, a broad, square ridge, which is continued backward as far as the commencement of the zygomatic arch.

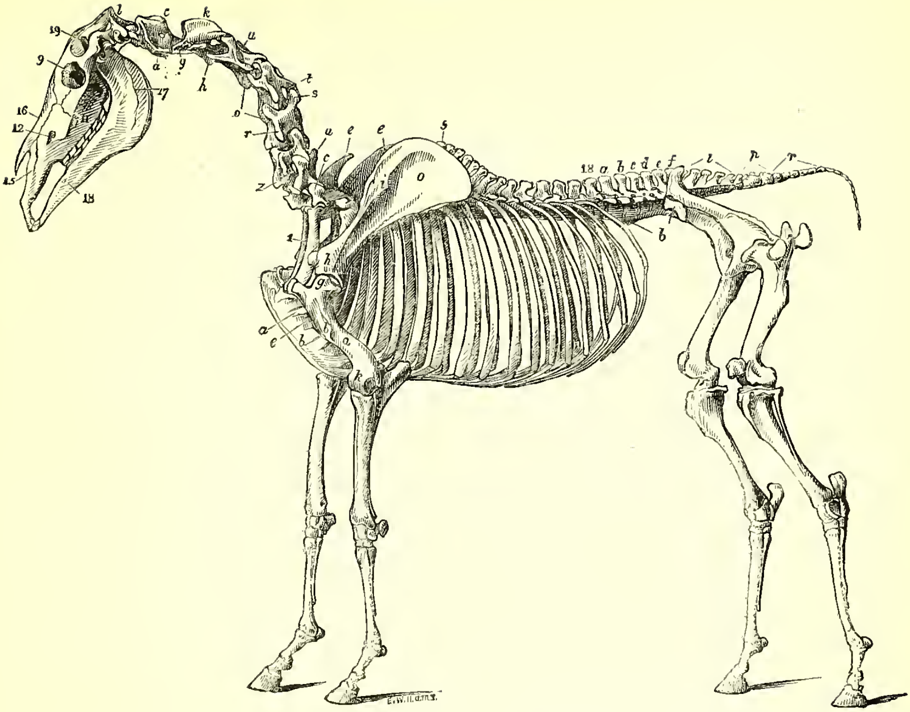
The palatine bone is deeply notched and very narrow, not extending forward beyond the penultimate molar tooth. This bone merely forms a narrow border around the meso-pterygoid fossa, but it composes more than two thirds of the pterygoid alæ. In the floor of the orbit it mounts upwards, between the maxillary bone on one side, and the two sphenoids on the other, as far as the os frontis, but it does not come in contact with the lachrymal. The external pterygoid process of the sphenoid runs along the palatine externally, and extends beyond it, but the internal pterygoid process is distinct from the sphenoid, forming a long and narrow tongue-like process, which, after having covered the lateral suture of the anterior end of the posterior sphenoid, extends obliquely over the centre of the pterygoid process of the palatine, and proceeds to form a bony hook, situated upon the side of the great palatine fissure.

Spinal column.—The *cervical vertebræ* of the horse are, as in all mammiferous quadrupeds, seven in number; their proportions are massive, and the whole series forms a chain of great strength and considerable flexibility. All the posterior vertebræ of the neck have in the horse a square or oblong shape, and both the spinous and transverse processes are short and stunted, so as not to interfere with that freedom and extent of motion which is essential in this portion of the spine.

The *atlas*, as in man and other mammifera, presents characters peculiar to itself. The body of this bone is entirely suppressed, its place being supplied by the two articulating surfaces appropriated to the reception of the condyles of the occipital: the superior lamina are broad and flat, and the superior spinous apophysis is not developed; whilst, instead of transverse processes, the vertebra is prolonged laterally into two broad alæ, into which numerous muscles are implanted. In the horse it may be remarked that the entrance of the canals for the passage of the vertebral arteries, instead of being situated at the posterior edge of the transverse apophyses, is placed upon its upper surface, but in other respects this bone presents no peculiarity worthy of special notice.

Axis.—The configuration of the second cervical vertebra in most quadrupeds differs considerably from what is met with in the human subject, owing to the horizontal direction of the neck, and the unfavourable position in which the head has to be sustained. This difference is most remarkable in the arrangement of the spinous process, which, instead of being merely a prominent tubercle, as in man, is prolonged into a vertical crest that

Fig. 497.



Skeleton of the Horse. (*After Stubbs.*)

Skull.—9, orbit ; 11, 12, superior maxillary bone ; 12, infra-orbital foramen; 15, intermaxillary; 16, os nasi; 17, 18, 19, lower jaw; 18, mental foramen; 19, coronoid process. *Cervical region.* — *a*, *c*, the atlas; *g*, *h*, *k*, the vertebra dentata; *o*, body; *r*, transverse; *s*, *t*, oblique, and *u*, spinous processes of cervical vertebræ ; *z*, process from the root of the transverse process of the sixth cervical vertebræ, assisting with its fellow to form the groove in which the longus colli muscle is lodged. *Dorsal region.*—*c*, oblique, and *e*, *e*, spinous processes of the two anterior dorsal vertebræ; 5 to 18, continuation of dorsal spinous processes. *Lumbar region.*—*a*, *b*, *c*, *d*, *e*, *f*, lumbar vertebræ; *l*, the sacrum; *p*, superior, and *r*, inferior, caudal vertebræ. *Sternal region.*—*a*, *b*, *c*, osseous and cartilaginous pieces of the sternum with the cartilaginous attachments of the true ribs. *Shoulder.*— *h*, *i*, *o*, the scapula; *b*, *g*, *k*, the os humeri.

sometimes advances forwards above the atlas and is prolonged posteriorly above the third, or even the fourth, cervical vertebra, thus affording an ample expansion for muscular attachments. In the Solipeds, this spinous crest (*k*) is but moderately developed, extending backwards so as to overlap the third vertebra to some extent ; but its anterior prolongation is wanting. The transverse apophyses are short, and perforated by the vertebral canal, while the articular processes are but moderately developed, and directed backwards to articulate with those of the succeeding vertebra.

The five posterior cervical vertebræ are remarkable for their strength and mobility; their bodies are of great proportionate size, and articulated together by broad sub-globular surfaces that allow a considerable extent of motion ; the vertebral laminæ are broad and massive, and the articular processes well developed and connected together by large articulating surfaces. The spinous processes are almost wanting except upon the sixth and seventh vertebræ, that belonging to the latter being of considerable size and turned backwards, so as to represent the commencement of the dorsal series of spines. The bodies of the sixth and seventh vertebræ of the neck, more particularly of the former, are prolonged inferiorly into a central crest of considerable size, which projects downwards and backwards, and gives origin to the *longus colli*, which muscle is likewise lodged in a kind of groove formed by osseous plates derived from the transverse processes.

The *dorsal vertebræ* in the Solipeds are invariably eighteen in number, and are distinguished by the shortness of their transverse apophyses, each of which is provided with an articulating surface, whereby it is connected with the corresponding rib as well as by similar articulations situated on each side upon the anterior and posterior extremities of their bodies to which the heads of the ribs are affixed. The spinous processes of the anterior dorsal vertebræ are of great length, and dilated at their extremities, where they give origin to the broad elastic cervical ligament by means of which the weight of the

head is in a very material degree supported; posteriorly, the spinous processes of the dorsal region become gradually shorter, and their extremities broad and flattened, so as gradually to approximate in their shape those of the lumbar region.

The *vertebræ of the loins* are, in the Solipeda, usually six in number: such is the case in the horse, zebra, and quagga; but in the ass there are but five lumbar vertebræ. This portion of the vertebral column is, in the class under consideration, possessed of great strength; the bodies of the vertebræ are broad and firmly bound together; the transverse processes of remarkable length and power; the articulating apophyses strong and broadly connected with each other, while the spinous processes, which are of great breadth, are either quite straight or inclined forward.

The *sacrum* in all the Solipeda is composed of five vertebræ consolidated into one piece, and, with that exception, scarcely different from the vertebral pieces that immediately precede and follow it. In the horse, as in most quadrupeds, the sacrum is much narrower in proportion than in the human subject, and forming, moreover, a continuous straight line with the rest of the spinal column, allows of much more freedom of motion in this part of the skeleton than is possible in the human subject; and this is much increased by the obliquity of the junction between the sacrum and the iliac bones. The articulation, moreover, between the last lumbar vertebra and the sacrum, still further adds to the mobility of these parts; for in the horse, the oblique processes of that vertebra are connected with the sacrum by means of articulating surfaces of very large size, so that from the combination of all these circumstances, there is a springiness given to this region of the vertebral column, the importance of which, in galloping or leaping, is at once conspicuous.

The *caudal vertebræ* in the solipeds vary in number from seventeen to twenty-one; but of these, the upper ones only resemble true vertebræ. Even in the first caudal vertebra, the inferior oblique processes become obliterated, and as we descend, all the vertebral apophyses rapidly disappear: at the second bone of the tail, the spinal laminæ no longer rise high enough to enclose the spinal canal; but resemble two short processes; and at about the fifth or sixth, all vestiges of them are lost, nothing remaining but the bodies of the vertebræ of a cylindrical shape and slightly enlarged at each extremity, until we approach the last, where all regularity of form is lost.

Thorax. — The *sternum* of the solipeds is considerably compressed towards its anterior extremity, which is moreover prolonged to some extent beyond the insertion of the first rib, so as to give to the whole chest a carinated appearance, which forcibly reminds the anatomist of the thorax of a bird. Posteriorly, the carinated form disappears, and the sternum becomes broad and flattened where it receives the cartilages of the posterior true ribs. The sternum of the horse is composed of several osseous pieces bound together by strong ligamentous and cartilaginous connections.

The *ribs* are eighteen in number, so that the thorax is prolonged very far backwards towards the pelvis. The anterior ribs are broad and massive; but of these, eight only are attached to the sternum: the posterior or false ribs gradually become more slender as they recede backwards to expand over the cavity of the abdomen.

Anterior extremity.—The frame-work of the shoulder in the Solipeda, as in all ungulate quadrupeds, is composed of the scapula only; the coracoid apparatus being dubiously represented by a rudimentary apophysis, and the clavicle is totally wanting in circumstances which allow of the close approximation of the shoulder blades to the sides of the chest, and thus cause the weight of the body to be transmitted perpendicularly to the ground.

The shape of the *scapula* (*fig.* 498. *o*) is almost that of an isosceles triangle, the spinal costa, which is about half the length of the other two, having its angles rounded off. The spine of the scapula is prominently developed, and towards its upper third, projects posteriorly, so as to form a considerable recurved process (*i*); as it approaches the neck of the bone, however, the scapular spine becomes quite obliterated, spreading out upon the margin of the glenoid cavity (*h*), so that no acromion process exists in these quadrupeds.

The *humerus* (*fig.* 498. *e, b, k*) is short, but of great strength, and the muscular imprints strongly marked.

The *forearm* is almost exclusively formed by the *radius* (*fig.* 498. *o, r*), the strength of which is in accordance with the enormous weight it has to sustain, while the *ulna* is reduced to a mere appendage (*fig.* 498. *s, t, u*), which in the adult animal is completely consolidated with its posterior surface, the line of demarcation between the two being only indicated by a furrow which, towards the upper extremity of the forearm, deepens into a slight fissure. The olecranon process is, however, of large size, and, by its projection posteriorly, affords a powerful purchase to the massive extensor muscles inserted into this portion of the limb. From the above arrangement of the bones of the forearm, it is manifest that all movements of pronation and supination are here out of the question; the limb must remain constantly fixed in a state of pronation, in which condition it is anchylosed, and thus acquires a firmness and steadiness which would be quite incompatible with more extensive movements.

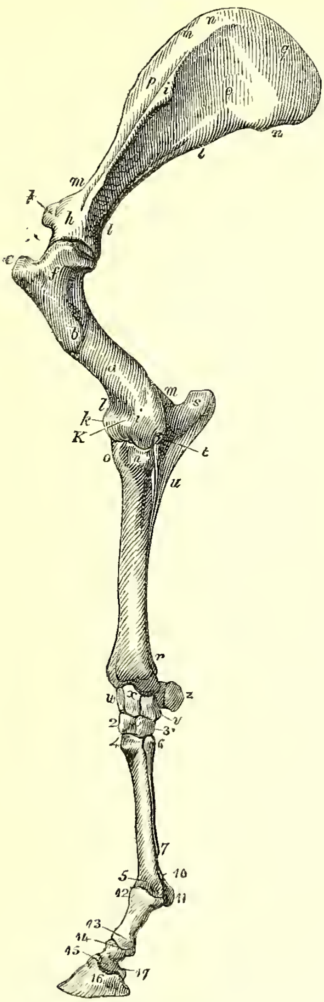
The *carpus* in the Solipeda consists of seven bones arranged in two rows, — of which four are situated in the first, and three in the second.

The upper series consists of the representative of the *os scaphoides* of the human subject (*fig.* 498. *w*); of the *os lunare* (*x*); of the *cuneiforme* (*y*); and of the *os pisiforme* (*z*).

In the lower series, the *os trapezium*, which supports the thumb of the human hand, does not exist in the horse; but the *trapezoid* (not

seen in the figure); the *os magnum* (2.); and the *unciforme* (3.) are all of them readily identified.

Fig. 498.



Osteology of the Horse — Bones of the anterior Extremity.

Scapula.— *h*, its neck; *i*, spine; *k*, coracoid apophysis; *l*, *l*, inferior costa; *m*, *m*, superior costa; *n*, *n*, base; *o*, fossa subspinalis; *p*, fossa supra-spinalis.

Os humeri. — *a*, shaft of the bone; *b*, protuberance into which the teres major is inserted; *e*, bicipital protuberance; *f*, neck of the humerus; *i*, external condyle; *K*, double articular suface, articulated with the radius; *k*, internal condyle; *l*, anterior fossa which receives the upper head of the radius, when the fore-arm is bent; *m*, posterior sinus, for the reception of the olecranon of the ulna, when the fore-arm is extended.

Radius. — *n*, its upper head; *o*, protuberance for the insertion of the tendon of the biceps; *r*, its lower extremity.

Ulna.— *s*, the olecranon process; *t*, its articulation with the humerus; *u*, continuation of the bone which in aged horses becomes united with the radius.

Bones of the carpus.— *w*, Scaphoides; *x*, Lunare; *y*, Cuneiforme; *z*, Pisiforme or Orbiculare; 2, Os magnum; 3, Unciforme.

Metacarpus.— 4, 5. The great metacarpal or cannon bone. 6, 7. Rudimentary external metacarpal bone. 10, 11. Sesamoid bones.

Fore-foot. 12, 13. Proximal phalanx or great pastern bone. 14, 15. Middle phalanx or lesser pastern or coronary bone. 16. Terminal phalanx or coffin-bone. 17. Sesamoid bone.

The *metacarpal bones* are in the horse consolidated into one large piece, called by farriers the shank or cannon bone, and two smaller supplementary pieces, which seem merely appendages to the former.

The large cannon bone (*fig.* 498. 4, 5.) is formed by the union of two metacarpal bones indissolubly conjoined, — viz. of those which support the ring and middle fingers in the human hand; these conjoined, here form a massive piece, the upper end of which articulates with the carpus, while its distal extremity sustains the first joint of the foot.

A second or supplemental piece (*fig.*498.6,7.) is simply a rudiment representing the internal metacarpal bone of the human skeleton, or that which in man supports the little finger; superiorly this piece presents an articulating surface, which articulates with the unciform bone of the carpus, but inferiorly, there being no finger for it to support, it gradually dwindles away to a mere splint, which is applied against the ulnar aspect of the preceding bone.

The third bone of the metacarpus is equally rudimentary as the last, and consists of a similar styliform bone applied against the opposite side of the shank bone, and obviously representing the metacarpal bone of the fore finger.

The fore foot of the horse is composed of three bones, representing the first, second, and third *phalanges* in the fingers of the human hand; but extraordinarily changed in their appearance. Of these, the first (*fig.* 498. 12, 13) is equivalent to the bones of the first phalanges of the ring and middle fingers in the human subject, as is indicated by a central groove, showing this piece to be composed of two lateral halves — this bone in the horse is called the "*great pastern.*"

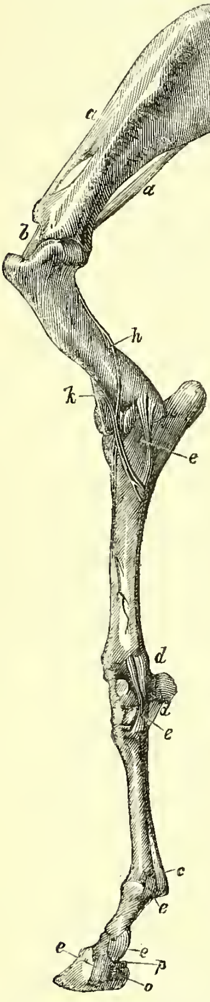
The second piece (*fig.* 498. 14, 15.) corresponding with the second phalanx, is named, in common language the "*little pastern,*" while the third (16), the representative of the third phalanx, a bone of very large size and crescentic shape, has received from farriers the name of the "*coffin bone.*"

In addition to the above may be noticed two *sesamoid bones* (10, 11) implanted in the flexor tendon of the foot, as it passes behind the articulation between the cannon bone and the great pastern, and a third lying over the posterior part of the articulation, between the coffin bone with the coronary bone, or between the two distal phalanges.

Posterior extremity. — The *pelvis* of the solipeds, both in its disposition and in the shape of the bones composing it, differs in many important particulars from that of man, and even of the generality of quadrupeds. The body of the ileum is elongated into a sort of

neck, while its crest and spine, extending themselves outwards almost at a right angle with the body, give the whole bone a shape somewhat like that of the letter T, or of a hammer, of which the body of the bone will form the handle, while the extremity of one of its branches is articulated to the side of the sacrum, and the other forms a broad expansion, the inner surface of which is turned obliquely towards the spinal column. The body of the ileum joins the ischium and pubis at a very obtuse angle, the cotyloid cavity being excavated in the usual manner in the line of junction between the three bones.

Fig. 499.

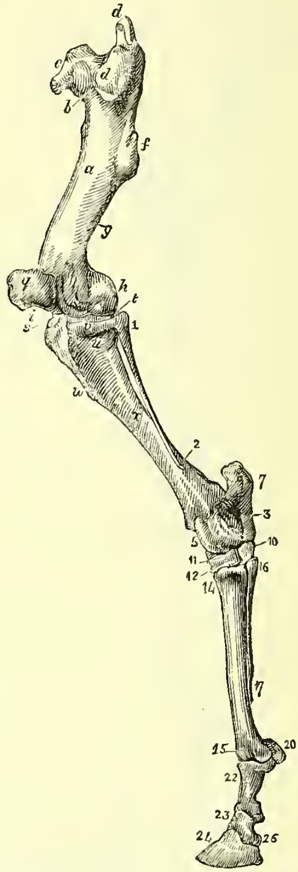


Ligaments of the anterior extremity of the Horse.

a, a, Ligaments of the scapula; *b,* capsular ligament of the shoulder-joint; *h,* radial nerve; *k,* capsule of elbow-joint; *d, d, d, e, e, e,* ligaments of the elbow, carpus, and phalanges; *o,* outer cartilage of the hoof; *p,* inner cartilage of the hoof.

The *os femoris* in the Solipeda is very strong and massive, with well developed trochanters, and prominent ridges for the attachment of the muscles implanted into it: it is however so short as to be entirely concealed within the flesh and integuments of the trunk, so that what is ordinarily designated the thigh in these quadrupeds is in reality the muscular portion of the leg. Inferiorly the articulating surface that sustains the patella is no longer, as in the human subject, continuous with that of the knee-joint, but forms a distinct articulation upon which the patella (*fig.*500. *q*) plays during the movements of the leg.

Fig. 500.



Osteology of the Horse.— Bones of the posterior Extremity.

Femur.— a, Body of the bone; *b,* its neck; *c,* the head incrusted with cartilage; *d, d,* trochanter major, or "spoke"; *f,* projection of the linea aspera, into which the glutæus externus is inserted; *g,* fossa, whence arises the gastrocnemius externus and plantaris; *h,* the external condyle; *i,* cartilaginous surface supporting — *q,* the patella.

s, t, external and internal semilunar cartilages of the knee-joint.

Tibia.— u, its upper head; *v,* articular surface, entering into the composition of the knee-joint; *w,* surface for the insertion of the ligamentum patellæ; *x,* shaft of the bone.

Fibula. — 1, Its upper extremity; 2, its lower end gradually diminished to a point.

Tarsus.— 3, 5, Astragalus or cockal bones; 7, os Calcis; 10, os Cuboides; 11, os Naviculare; 12, os Cuneiforme.

Metatarsus.— 14, Upper extremity, and 15, lower extremity of the great metatarsal or cannon bone. 16, 17, rudimentary external metatarsal bone; 20, Sesamoid bone.

Hind-foot.—22. Proximal phalanx, or great pastern; 23. Middle phalanx, or lesser pastern, or coronary bone; 24, Last phalanx or coffin bone; 25, Sesamoid bone.

The *leg* is in the Solipeda almost exclusively formed by the *tibia*, which is of great strength, and very massive towards its upper extremity, where the ridges for muscular attachment stand out in bold relief; inferiorly it becomes more slender, and approaches nearer to a cylindrical shape, expanding again inferiorly to form the articulating surface for the ankle joint.

The *fibula* (*fig.* 500. 1, 2.) is even more rudimentary in its development than the ulna in the anterior extremity, being, in fact, nothing more than a long spiculum of bone implanted among the muscles, and laid like a slender splint along the outer and posterior angle of the tibia, with which it is firmly connected by ligamentous attachments in the vicinity of the knee-joint, whence it descends separated by a small interval from the tibia as far as the middle of that bone, to which at this point it becomes closely applied, and then, gradually becoming more and more attenuated, is towards the lower third of the leg completely lost.

The bones of the *tarsus* in the horse are, 1st, the astragalus, or "cockal-bone," as it is vulgarly named (*fig.* 500. 3, 5.), the os calcis, or "heel-bone" (7), the cuboid (10), the navicular (11), the middle cuneiform and the lesser cuneiform (12). The internal or great cuneiform bone is here wanting, as also are the bones of the great toe, which, when present, it is destined to support.

The bones of the *metatarsus*, like those of the metacarpus, are three in number,—viz. one large central or cannon bone, and two lateral rudimentary pieces. The central piece (*fig.* 500. 14, 15.), which supports the entire weight of the body, is apparently composed of the conjoined metatarsal bones belonging to the second and third smaller toes; in the human skeleton the line of demarcation between the two being indicated by a deep longitudinal groove: by its upper extremity this bone articulates with the three lower bones of the tarsus; while inferiorly it presents a smooth articular surface, whereby it supports the first phalanx of the foot. The external rudiment (*fig.* 500. 16, 17.) is an imperfect metatarsal bone, occupying the place of that which in the human subject supports the little toe: by its upper extremity it articulates with the cuboid bone of the tarsus, while inferiorly, owing to the deficiency of the corresponding toe, it forms no articulation. The internal rudiment represents the metatarsal bone of the first of the small toes in the human foot: superiorly it articulates with the lesser cuneiform bone of the tarsus (12), whence, as it descends, it gradually diminishes in size, and is lost before it reaches the foot.

The bones of the hind foot resemble those already described in the anterior extremity, and are distinguished by similar names, the first *phalanx* of the solitary toe being the great pastern, the second the little pastern or coronary bone, and the third, or that which supports the hoof, the coffin bone: there are likewise the *sesamoid bones* (20), behind the articulation, between the cannon bone and the first phalanx, and also between the coronary and coffin bones (25).

Myology. — The myology of quadrupeds is, in many points of view, a subject of particular interest, more especially in those races which are far removed from man in their general habits or in the configuration of their skeleton. In the case of the Solipeds, owing to the exceedingly aberrant structure of their extremities, the disposition of their muscular system becomes a very important subject of inquiry, and it is partly from this cause, and partly from the necessity of obtaining an accurate knowledge of the anatomy of animals so valuable to mankind, that the myology of the horse and its congeners has been studied with great care, and delineated with extraordinary zeal and perseverance. It is for these reasons that we shall in the present article describe at some length this portion of their economy, premising that the details here given will be found more or less applicable to quadrupeds generally, except where obvious peculiarities of structure belong to the class which forms the more immediate subject of our study.

Panniculus carnosus. — On removing the skin, the entire body is in most quadrupeds found to be invested with a muscular covering, the thickness and consequent importance of which varies in different parts. In the human subject the traces of this fleshy pannicle are very feeble, being confined to certain regions,— such as the anterior part of the neck, the palms of the hands, &c.; but in the horse it forms a much more important investment, giving mobility to the integument, and materially contributing to the support and defence of various organs. This fleshy covering is very thick in the anterior region of the neck, whence it extends downwards upon the anterior extremities, and, becoming tendinous, is extensively inserted in conjunction with the tendons of the latissimus dorsi and teres major, into the external surface of the humerus. From this point strong muscular fibres pass downwards over the muscles of the fore-arm, where they terminate in a broad fascial expansion which embraces the lower part of the fore-leg. Another strong portion of this fleshy tegument spreads over the sides and loins, where it degenerates into a tendino-membranous layer, extending downwards as far as the penis, which it likewise invests with a carneo-membranous sheath. It likewise encases the buttocks and thighs in a strong covering of fleshy and tendinous fibres, which

spreads downwards over the fascia lata to the hind leg.

In describing the other parts of the muscular system, it will be necessary to divide them into their appropriate regions, and in so doing, we shall follow the arrangement usually adopted in describing the human subject, beginning with the

Proper muscles of the spine. — The long muscles of the spine, — viz. the spinalis and semi-spinalis dorsi, longissimus dorsi and sacro-lumbalis — present a disposition very similar to what occurs in the human subject.

The *spinalis dorsi* takes its origin from the spinous processes of the lumbar and posterior dorsal vertebræ, as well as from the broad fascia of the loins, and running forwards is inserted by distinct tendons into the spines of the anterior vertebræ of the back. Its continuation, the *spinalis cervicis*, is in the horse of great strength and importance: its origin commences from the second spine of the back, which origin is continued for about one third of the way down that spine towards its root: it arises likewise from the third dorsal spine and the ligamentum nuchæ; from these origins it runs forward to be implanted by strong and distinct tendons into the spines of the anterior cervical vertebræ.

The *longissimus dorsi* is situated immediately external to the spinalis, taking its origin from the common mass of muscle that arises beneath the lumbar fascia, as well as from the spinous processes of the loins and sacrum, whence it runs forward to be inserted by a double set of tendons into the transverse processes of the loins and back, and also into the posterior ribs near their angles. Its continuation, the *transversalis colli*, is likewise of considerable strength, but offers nothing worthy of remark.

The *sacro-lumbalis* arises, in conjunction with the latissimus dorsi, from the back of the sacrum, and also by flat tendons about

Fig. 501.

Myology of the Horse. (*After Stubbs.*)

Head.— *n*, Levator anguli oris; *o*, orbicularis oris; *t*, anterior dilator of the nostril; *w*, masseter; *k*, septum narium; 4, vena angularis. 12, Anterior cartilage of the external ear.

Neck.— *a*, Coraco-hyoideus; *g*, transversalis cervicis; *l*, trachelo-mastoideus, or complexus minor; *m*, complexus; *y*, the longus colli.

Shoulder.— *c*, Triceps extensor cubiti; *h*, tendon of the biceps flexor cubiti.

Forearm and anterior extremity.— *a*, *b*, *c*, Extensor carpi radialis; *h*, extensor digitorum communis; *q*, analogue of the extensor minimi digiti; 6, 9, ligaments; *t*, vena plantaris interna; *u*, nervus plantaris internus.

Trunk.— *d*, serratus minor posticus; *h*, serratus major posticus; *l*, serratus major anticus; *o*, external intercostals; *p*, internal intercostals; *q*, rectus abdominis; *x*, obliquus internus.

Hinder extremity.— *b*, glutæus medius; *h*, rectus femoris; *n*, vastus externus; *u*, *w*, 21, 26, 24, extensor digitorum pedis; 6. plantaris and gastrocnemius.

half the breadth of the muscle from the superior edge of all the ribs, except two or three of the most anterior; and its slips are inse ted by as many distinct tendons into the inferior edge of all the ribs, except two or three of the hindmost, and also into the transverse process of the seventh vertebra of the neck. The continuation of this muscle, the *cervicalis descendens*, offers nothing remarkable.

The *multifidus spinæ*, in the dorsal region arises by numerous tendinous origins from the transverse processes of the vertebræ of the back, loins, and sacrum, near their posterior protuberances, each slip running forwards to be inserted into the spinous process of the vertebra in front of that from which it derives its origin, the whole forming a thick mass, which fills up the hollow situated between the spinous and transverse processes. In the neck a similar disposition exists.

The *intertransversarii colli* take their origins from the roots of the oblique processes of the cervical vertebræ, and from between these and the transverse processes: in the horse they are of great strength and importance, running forwards to be inserted into the transverse processes of the vertebra in front of that from which they arise. In addition to the above there is a set of muscles named by Stubbs the *intervertebrales*, which do not exist in the human subject: these arise from the ascending oblique processes of the five inferior vertebræ of the neck, and from the space betwixt the oblique processes of the uppermost vertebræ of the back: they are each of them inserted into the lateral parts of the bodies of the vertebræ above their origin.

The *longus colli* is the only muscle, exclusively appropriated to the movements of the spine, situated in front of the spinal column. This muscle, in the horse, arises from the transverse processes of the third, fourth, fifth, and sixth vertebræ of the neck, from which origins it runs upwards to be inserted by distinct tendons into the anterior part of the bodies and transverse processes of the vertebræ above them, and into the anterior surface of the atlas.

The *quadratus lumborum* offers the same disposition as in the human subject.

The tail in quadrupeds, from its great development, requires for its movements a special set of muscles, of which scarcely any traces exist in the human subject. This organ in the horse is susceptible of three kinds of movements. It can be straightened or elevated, bent or brought downwards, and lastly carried to either side. These movements, again, by their combinations, produce secondary effects, so that the tail becomes susceptible of very extensive motions; and, in such quadrupeds as have this part very largely developed, it even supplies the place of a hand, so completely is it under muscular control.

In order to effect these different movements, three* distinct sets of muscles are employed, which are arranged upon the same plan as the long muscles in other parts of the spinal column; that is to say, they arise by numerous tendinous slips, and are inserted in a similar manner, the slips of origin and insertion running, of course, in opposite directions: the latter, moreover, are prolonged to a much greater extent than in the rest of the spinal column, and firmly bound down to the vertebræ by tendinous sheaths, so as to add as little as possible to the bulk of the tail.

The *muscles which raise or straighten the tail* are all situated upon its upper aspect: they are, first,

The *sacro-coccygeus superior* (*lombo-sus-caudien*). This muscle arises in the horse from the inferior or posterior edge of the third spinal process of the os sacrum, and from the spines, edges, and interspinal ligaments of the sacral vertebræ behind that point, as well as from those caudal vertebræ that are possessed of spinous apophyses. The fleshy mass formed from these origins gives off numerous slender tendons: the first of these is the shortest, and runs inwards to be inserted into the base of the first caudal vertebra, in which the articular apophyses are wanting. The second tendon is inserted in a similar manner into the succeeding vertebral piece; the third into the next, and so on to the end of the tail. The number of the tendons given off is, of course, determined by that of the vertebræ. Each tendon is lodged in a sort of ligamentous canal, which forms a sheath for it throughout its whole course. When these two muscles act in concert the tail is necessarily raised upwards.

The *interspinales superiores* (*spinalis obliquus; lombo-sacro-coccygien* of Vicq d'Azyr). These muscles are a continuation of the interspinous muscles of the spine; but as the spinous processes of the tail are short, and frequently replaced by two tubercles answering to rudiments of the oblique processes, these muscles are here disposed obliquely, being more widely separated posteriorly than they are in front.

The *muscles which depress the tail* or bend it downwards all take their origin in the interior of the pelvis, and are prolonged to a greater or less extent along the inferior aspect of the tail. These form, when completely developed, four pairs, or four pairs of series, of muscles.

1. The *ileo-coccygei* (*ileo-sous-caudien* of Vicq d'Azyr) arise from the internal or pelvic surface of the ossa ilei, and, forming an elongated fleshy belly in the interior of the pelvis, terminate beneath the root of the tail, which they will consequently depress with considerable force against the anus.

2. The *sacro-coccygeus inferior* (*sacro-sous-caudien*) is the antagonist of the sacro-coccygeus superior, above described, which in structure it exactly resembles. This muscle takes its origin from the inferior surface of the sacrum and of the transverse processes of those caudal vertebræ in which these processes are developed, by a fleshy belly which gradually diminishes in thickness, and termi-

* Cuvier, Anat. Comp. tom. i. p 275.

nates by forming as many tendons as there are caudal vertebræ without transverse processes. These tendons are received into sheaths resembling those upon the upper surface of the tail, and are inserted successively into the base of each caudal vertebra, beginning about the seventh.

3. The *interspinales inferiores* (*sub-caudales*, *inter-coccygeus* of Vicq d'Azyr). These are situated beneath the mesian line of the tail. They commence underneath the articulation between the first and second caudal vertebræ, and form an elongated fleshy belly, which, in some quadrupeds that have the tail largely developed, become first of all implanted into V-shaped bones derived from the fourth, fifth and sixth vertebræ of the tail: they receive, moreover, from time to time additional fleshy slips, which go on continually diminishing in size, and give off tendons to be inserted successively into the inferior aspect of the base of each caudal vertebra.

4. The *pubo-coccygeus* (*pubo-sous-caudien*). This is a thin muscle, derived from the whole extent of the upper margin of the pelvis, and having the appearance of a fleshy membrane, the fibres of which are gradually collected into one point to be inserted beneath the tail into tubercles situated upon the base of the fourth and fifth vertebræ. The action of this muscle will produce an effect similar to that of the ileo-coccygeus.

The *muscles adapted to move the tail laterally* are arranged in two sets.

1. The *ischio coccygeus externus* (*ischio-caudien*) arises from the posterior or internal surface of the ischium, a little below and behind the cotyloid cavity, from which origin it runs backwards to be inserted into the transverse processes of the anterior caudal vertebræ. This muscle is improperly called by Stubbs the *levator ani*, because in the horse a few fibres of it are connected with the termination of the rectum.

2. The *intertransversales* (*intertransversal* of Vicq d'Azyr) extend in the form of musculo-aponeurotic layers over all the transverse processes that are developed in the caudal region, their tendons of insertion being most distinctly seen upon the upper surface of the tail.

In animals that have the muscular apparatus of the tail completely developed the muscles are found to consist of eight distinct sets, —viz., two superior, two lateral, and two inferior. In the horse some of these are deficient, or exist only in a rudimentary condition. To see them in their full state of development they must be examined in animals provided with long and mobile tails, such as the prehensile-tailed monkeys, the opossums, the lion, and, more especially, in the kangaroo and beaver.

Muscles derived from the spinal column which serve immediately for the movements of the cranium. — These have nearly the same origins as in the human subject, but are comparatively of much greater strength, owing to the inclined position of the head with respect to the vertebral column. They may be divided into such as proceed, 1st, from the atlas; 2nd, from the axis; and, 3rd, from the posterior cervical vertebræ and ligamentum nuchæ. To the first set belong —

1. The *rectus capitis posticus minor*, or rather *medius*, arising, as in the human subject, from the atlas; from this origin it runs to be inserted by a short and broad tendon into the occiput.

The other muscles belonging to the atlas — namely, the *rectus anticus*, the *rectus lateralis*, and the *obliquus superior* — offer the same position as in the man.

The muscles derived from the axis — viz. the *rectus posticus major* and the *obliquus inferior* — are likewise similarly disposed in all quadrupeds.

The muscles arising from the other cervical vertebræ are

The *complexus*, which, commencing from the upper oblique process of the third vertebra of the neck, continues its origin from all the oblique processes of the neck below that point, as well as from the upper oblique process of the first vertebra of the back, also by a pretty strong tendon from the transverse processes of the second and third dorsal vertebræ; from these origins it runs forwards to be inserted by a strong round tendon into the occiput close to its fellow of the opposite side: in this course it is connected by numerous tendinous processes with the ligamentum nuchæ. That portion of the complexus usually distinguished by the name of *digastricus colli* is in the horse undistinguishable as a distinct muscle.

The *trachelo-mastoideus*, or *complexus minor*, arises from the oblique processes of the third, fourth, fifth, sixth, and seventh cervical and first dorsal vertebræ, and from the transverse processes of the second and third vertebræ of the back; it runs forwards external to the last-mentioned muscles to be inserted by a strong tendon into the mastoid apophysis of the temporal bone. The above muscles are overlapped by the

Splenius capitis (*cervico-mastoiden*), which, arising by strong tendinous processes from the spinous processes of the two superior dorsal and two last cervical, and also extensively from the ligamentum nuchæ, runs forward to be inserted into the transverse processes of the fifth, fourth, and third cervical vertebra, and into the transverse ridge of the occipital bone. It is remarked by Cuvier that in carnivorous quadrupeds the splenius is not inserted into the transverse processes of the cervical vertebræ as it is in herbivorous animals and in the human subject, in which the latter portion is sometimes sufficiently distinct to obtain the name of *splenius colli* in contradistinction to the *splenius capitis*. It is likewise remarkable that in the camel, if the splenius exists at all, it is extremely thin and difficult to display by dissection.

Muscles of the ribs and sternum. — The muscles derived from and inserted into the ribs and sternum are found in all quadrupeds to

have the same general arrangement as in the human subject. In the horse, their disposition is as follows, beginning with those whose office is to raise the framework of the chest and thus assist in inspiration.

The *scaleni* differ in no remarkable respect from the corresponding muscles in the human body. The same may be said of the *intercostal muscles*, the *levatores costarum*, the *serratus posticus superior* (*dorso-costien*), the *serratus posticus inferior* (*lombo-costien*), and the *triangularis sterni* (*sterno-costien*), the two latter of which must be regarded as depressors of the ribs, and consequently acting the part of muscles of expiration.

In all quadrupeds possessing a greater number of ribs, and consequently a more capacious thorax than man, the attachments of the *diaphragm* are found to be much further removed from the margins of the false ribs than in the human subject: nevertheless the position which it occupies, and its connections in the thoracic cavity, are similar in all mammiferous animals.

The *walls of the abdomen*, in the horse as in the generality of quadrupeds, are composed of five pairs of muscles, to which the same names are applicable as are bestowed upon them by the anthropotomist.

The *obliquus externus abdominis* (*costo-abdominien*) arises, by tendinous processes that indigitate with the origins of the serratus magnus, from the external surface of all the lower ribs, beginning at the fifth; and below the last rib it derives its posterior attachment from the fascia lumborum; from these origins, it runs backwards and downwards, terminating in a broad tendinous expansion, the terminations of which in the linea alba, os pubis, and Poupart's ligament, together with the formation of the external abdominal ring, are exactly as in the human subject.

The *obliquus internus* (*ileo-abdominien*) exhibits the usual arrangement, arising tendinous and fleshy from the crest of the ileum and pubic ligament, whence it mounts obliquely forwards to be inserted into the cartilages of all the lower ribs as far forwards as the ensiform cartilage of the sternum.

The *rectus abdominis* (*sterno-pubien*) is much more extensively developed in the horse than in human beings. Arising from the os pubis it passes forwards enclosed in its usual sheath to be inserted into the ensiform cartilage and into the cartilaginous terminations of the third, fourth, fifth, sixth, seventh, eighth and ninth ribs, and also into the sternum between the cartilages of the third and fourth ribs. There are even fleshy fibres derived from this muscle prolonged as far forwards as the articulation between the first rib and the sternum, which, by the old anatomists, was regarded as a distinct muscle, and named "musculus in summo thorace situs."

In many of the Carnivora the rectus abdominis is equally remarkable for its great length, and in some species it is even prolonged forwards to the very anterior extremity of the sternum. When the recti are thus largely developed the *pyramidales* do not exist.

Anterior extremity. Muscles of the shoulder. — It may readily be supposed that in the horse and other herbivorous quadrupeds not possessed of a clavicle, and, moreover, remarkable for the extreme simplicity of the structure of their scapular apparatus, these muscles undergo important modifications in their disposition and attachments, which it will be interesting to investigate. In the human subject the muscles specially appropriated to the movements of the shoulder are eight in number, — viz. the *serratus magnus*, the *pectoralis minor*, the *levator scapulæ*, the *rhomboideus*, the *trapezius*, the *omo-hyoideus*, the *subclavius*, and the *sterno-cleido mastoideus*, all of which concur in producing the various movements of which the human shoulder is susceptible. Of these, it will be observed, the six first belong exclusively to the Scapula, except the *trapezius*, which is inserted extensively into the clavicle; whilst the operation of the two last is upon the clavicle only.

In quadrupeds the shoulder is furnished with the same muscles as those which are met with in man, only they present differences in their proportions and attachments, which are dependent upon the structure of the skeleton, or the particular requirements of the animal; and, moreover, they are provided with an additional muscle, of which no vestiges appear in our own bodies. In the horse, the arrangement of the muscular apparatus of the shoulder is as follows.

The *trapezius*, in all quadrupeds destitute of clavicles, or in which these bones are but imperfectly developed, presents an arrangement very different from what exists in such as have the clavicles completely formed: that part which would in the latter case have been the clavicular portion, becomes confounded with the deltoid and with the cleido-mastoid (here a very distinct muscle from the sterno-mastoid). From the combination of these three, there usually results a single muscle, which is implanted immediately into the humerus, and which, from its attachments, might be named the *masto-humeralis*. It is this muscle which is named by Stubbs the *levator humeri proprius*, and its posterior part *musculus ad levatorem accessorius*; and by the French hippotomists *muscle commun de la tête de l'encolure et du bras*. This clavicular portion of the trapezius is very distinct from the scapular portion, from which it is in many animals separated by the *trachelo-acromial* muscle, to be described further on.

In the horse, therefore, the Trapezius may be said to consist of that part only which is called the ascending portion in the human subject, and which is inserted into the posterior margin of the spine of the scapula. The *sterno-mastoid* is present, but the *levator anguli scapulæ*, the cleido-mastoid, and the clavicular portions of the *trapezius* and *deltoid* are all replaced by the muscular expansion above described, and which, taking its origin from the mastoid process of the temporal bone

and from the transverse processes of some of the superior cervical vertebræ, passes downwards in front of the head of the humerus and descends along the inner surface of the forearm, into which it is ultimately inserted.

The muscle of the shoulder which is proper to quadrupeds may be named the *trachelo-acromialis* (*acromio-trachelien*, Cuv., *acromio-basilaire*, Vieq d'Azyr). It arises in the horse from the transverse process of the atlas and of the four following cervical vertebræ (in the generality of quadrupeds from the three uppermost only); from this origin it descends towards the shoulder-joint, making its appearance externally between the two divisions of the trapezius, which it separates; it then spreads out over the acromial portion of the scapula, and descends as far as the middle of the humerus, where it is inserted. Its action will, of course, be to draw the shoulder upwards and forwards. This muscle, which exists in all the mammalia, with the exception of the human species, would seem to be in special relation with the quadrupedal mode of progression; and, as Cuvier observes, affords a striking example of the difficulty of establishing a good nomenclature in comparative anatomy: in some animals, it derives its origin exclusively from the cranium; and, in others, from the upper or lower cervical vertebræ. Its mode of insertion is equally various; in the tapir it is implanted into the aponeurosis which covers the deltoid muscle; while, in the horse, it has its insertion into the middle portion of the humerus by two aponeurotic tendons, which embrace the brachialis internus muscle.

The *serratus major anticus* (*scapulo-costien*), in the horse, arises from the transverse processes of the third, fourth, fifth, and sixth cervical vertebræ, and also from the external surfaces of the six superior ribs: its origins extending as far backwards as the insertion of the tendons of the sacro-lumbalis: from this extensive origin it passes backwards around the chest to be implanted into the base of the scapula, its insertion occupying nearly half of the internal surface of that bone. This muscle, Cuvier remarks, is much more extensively developed in quadrupeds than in the human subject; for, in all other mammalia, except in the orang-outang, it arises not only by digitations from the ribs, but also from the transverse processes of the vertebræ of the neck, an arrangement which becomes necessary in animals that walk upon four feet, in order to prevent the scapula from being pushed too far backwards towards the spine. This muscle, in fact, forms, with its fellow on the opposite side, a kind of sling, by which the trunk is suspended. The fact that it is equally extensive in its attachments in the Monkeys, is an additional proof that the usual mode of progression in these animals is on four feet: in these animals, indeed, the serratus magnus derives origins from all the cervical vertebræ, instead of from only a part, as in other mammifera. In the Cetaceæ that do not walk, and in the kangaroos which have their anterior limbs very small, the serratus magnus presents a corresponding feebleness of developments.

The *pectoralis minor* (*serratus minor anticus*) is, in the horse, represented by a muscle, which, arising from the sternum and from the first, second, third, and fourth ribs near their sternal terminations, runs upwards and backwards to be inserted into the superior costa of the scapula near the base of that bone; it also contracts tendinous attachments with the aponeurotic covering of the teres minor and other scapular muscles.

The *rhomboideus* arises, in the horse, entirely from the ligamentum nuchæ, and from the spines of the anterior dorsal vertebræ, whence it runs outwards to be affixed to the base of the scapula.

In monkeys and in the carnivorous quadrupeds the rhomboideus is continued upwards as far as the occiput, whence it derives an extensive origin; the occipital portion, indeed, is, in the Carnivora, separated from the rest so as to form a distinct muscle, called by some writers the *occipito-scapularis*, and, by Cuvier, "*rhomboïde de la tête*."

The *omo-hyoideus* is, generally, wanting in animals whose scapula presents no coracoid process: neither can there be any *subclavius* in animals that do not possess a clavicle: in the horse, however, the former of these is represented by a strong muscular fasciculus.

In this place it may be proper to notice the muscle named by the human anatomist *sterno-cleido-mastoideus;* but which, in the lower animals, is represented by two distinct muscles. One of these,

The *sterno-mastoideus*, or, as it might be named, sterno-maxillaris, arises, in the horse, from the anterior end of the sternum, and, running forwards strong and fleshy, is inserted by a flat tendon into the inferior maxilla underneath the parotid gland, sending, however, another tendon to be implanted into the root of the mastoid process.

The *cleido-mastoideus*, always a distinct muscle from the preceding, is, as we have seen above, in the horse and other non-claviculate quadrupeds, confounded with the clavicular portions of the trapezius and deltoid.

Muscles inserted into the humerus. — The movements of the humerus in the human body are effected by two sets of muscles: one derived from the trunk, the other from the framework of the shoulder. The former are the pectoralis major and latissimus dorsi; the latter, the supra-spinatus, the infra-spinatus, and the subscapularis proceeding from the surfaces of the scapula and the deltoid, teres minor, teres major, and coraco-brachialis, which take their origins from the processes. In the horse and in other quadrupeds, various circumstances render modifications in the arrangement of these muscles indispensable.

The *pectoralis major* (*sterno-humerien*), in the horse, arises, first, from the aponeurosis of the external oblique muscle of the abdomen; secondly, from the two lower thirds of the sternum; and, thirdly, from the supe-

rior part of the sternum for about one-third of its length. The first of these portions winds round to be inserted into the internal aspect of the head of the humerus; the second ends in a fascia, which descends downwards over the fore-arm, while the third, running in a transverse direction over the inferior portion, is inserted into the humerus along with the "levator humeri proprius" between the biceps and the brachiæus internus.

In all those mammalia which are destitute of complete clavicles, even in the Cetacea, there is a part of the sternal portion of the pectoralis major, which is inserted perpendicularly into the humerus, that joins the corresponding portion of the opposite side to form the *muscle common to both arms*," by the action of which the two fore-legs are made to cross each other.

The *latissimus dorsi* (*lombo-humerien*), in the horse, and in other quadrupeds, exhibits the same arrangement as in the human subject: it is, however, in the lower animals powerfully assisted in its action by the massy muscle already described (*cutano-humerien*), formed by the panniculus carnosus, a strong tendon from which is inserted into the humerus along with that of the latissimus dorsi. Both are intimately connected with the tendon of the teres major, and from this combination of tendons arises one of the heads of the triceps extensor cubiti.

The *supra-spinatus*, the *infra-spinatus*, the *subscapularis*, the *teres major*, and the *teres minor* have, in all quadrupeds, the same arrangement as in the human subject, the only differences being dependent upon the shape and proportions of the scapula.

The *deltoid* in all animals having their clavicles imperfect or wanting, is necessarily modified in its disposition to a very considerable degree. We have already seen when speaking of the trapezius, that its clavicular portion is in such cases blended with the anterior division of that muscle: that part only which takes its origin from the scapula remains to be noticed. Where the acromion is well developed, the deltoid may be divided into two portions; one derived from the acromion, the other proceeding from the spine and subjacent surface of the scapula: these two portions unite, and, decussating each other, form a common tendon, which is implanted into the deltoid ridge of the humerus. As the acromion process diminishes in size, the acromial portion of the deltoid becomes enfeebled in like degree, until at length, as in the horse, where there is no acromial projection, that part of the deltoid arising from the spine remains alone. Under these circumstances, this muscle is directed forwards in nearly the same direction as the infra-spinatus, and, both from its position and office has been named by hippotomists the "*abductor longus brachii.*"

The *coraco-brachialis* exists even in animals that have no coracoid process, in which case it takes its origin from a little tubercle situated upon the superior costa of the scapula. When the biceps arises by two heads, as in the human subject, the coraco-brachialis arises with the longer head by a common tendon; but when, as is the case in many quadrupeds, the biceps has but one origin from the humerus, the coraco-brachialis is in no way connected with that muscle.

Muscles of the forearm. — *Flexors.* — The *biceps*, in the generality of quadrupeds, has the same origins as in the human subject; one head arising from the neck of the scapula, the other from its coracoid process: these two heads uniting form a common tendon, which is inserted into the tubercle of the radius, and, by an aponeurotic expansion into the fascia covering the muscles of the forearm; but where the coracoid process of the scapula is deficient, as in the horse, and in the carnivora generally, the term "biceps" is no longer applicable to this muscle, seeing that it has but one origin from the margin of the glenoid cavity: in the rest of its course it is similarly disposed in all the mammalia.

The *brachiæus internus* (*humero-cubitien*) in all quadrupeds has the same arrangement as in the human subject. In the horse, the biceps and the brachiæus are by most writers named the "long and short flexors of the forearm."

Extensors. — The *triceps extensor cubiti* (*scapulo-olecranien*) is in the horse a muscle of prodigious strength, and consists of three portions similar to those named in the human anatomy the long extensor, the short extensor, and the brachialis externus (the great extensor, the middle extensor, and the short extensor of Bourgelat, and other writers on the anatomy of the horse). There is, moreover, a fourth portion, derived from the common tendon of the latissimus dorsi and teres major, by the intervention of which, it takes its origin from the inferior margin of the scapula.

The *anconæus* (*epicondylo cubitien*) exists in all quadrupeds.

As might be expected from the construction of the bones of the forearm, both the *pronator muscles* are in the Solipeda entirely wanting, as is the case in the Ruminantia and in the Pachydermata generally; nevertheless, in the elephant and in the hog-tribe the pronator teres is feebly developed; and, as the mobility of the bones of the forearm becomes more perfect, as in the Carnivora, Quadrumana and Marsupialia, both the pronators are found presenting the same arrangement as in the human body.

The *supinators* are quite obliterated in the Solipeda, as well as in the Ruminantia and Pachydermata.

Muscles of the carpus and metacarpus. — The muscles employed in bending the wrist are in our own persons the palmaris longus, the flexor carpi radialis longior, the flexor carpi radialis brevior, the extensor carpi radialis, the flexor carpi ulnaris, and the extensor carpi ulnaris; of these one only is inserted into the carpus, all the rest being attached to the metacarpal bones.

In all multi-digitate mammalia, such as the Quadrumana, Carnivora, Rodentia, and Eden-

tata, these six muscles exist and are disposed pretty nearly as in the human race; but in the Pachydermata and Ruminantia there is but one flexor carpi radialis. In all the above multidigitate animals, the muscles derived from the external condyle, and its vicinity by their co-operation, approximate the back of the hand towards the forearm, or, in other words, are extensors of the fore-foot; while those derived from the internal condyle have a contrary effect, and act as flexors of the hand. Should the flexor and extensor of the same side of the limb act together, the hand will be bent laterally in the corresponding direction.

In the Solipeda, where the movements of the wrist are strictly limited to those of flexion and extension, the disposition of these muscles is considerably modified.

The *extensor carpi radialis* is here single, arising from the anterior part of the external condyle of the humerus, and from the external surface of that bone for a considerable distance: it forms a strong fleshy belly, terminating in a powerful tendon, which runs to be inserted into the base of the anterior surface of the metacarpal or cannon bone. This muscle, called by Bourgelat the "*extenseur droit anterieur du canon*," seems, from the extent of its origin, to represent the long supinator and the two radial extensors of the wrist combined, and all three made to cooperate in the extension of the wrist.

The *flexor carpi radialis* (*epitrochlo-metacarpien*) arises from the external condyle of the humerus, and is inserted into the posterior surface of the base of the cannon bone, forming the antagonist to the preceding muscle: this is the "*flechisseur interne du canon*" of Bourgelat.

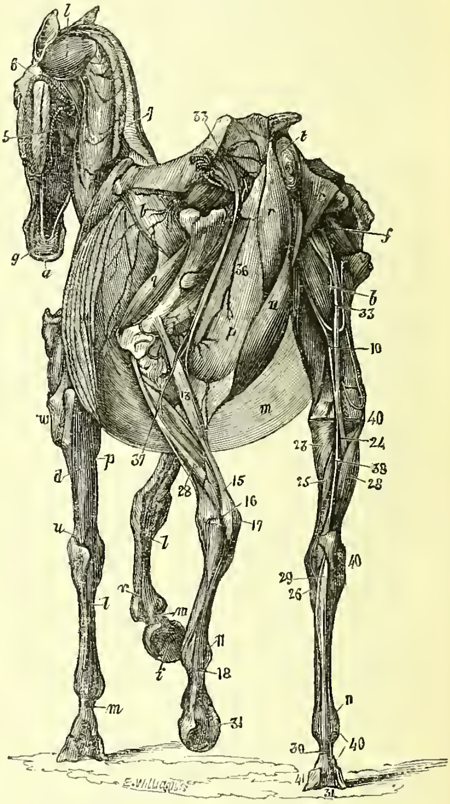
The *flexor carpi ulnaris* (*epitrochlo-carpien*) arises from the posterior part of the external protuberance of the os humeri, and also by a distinct head from the protuberance situated above the internal condyle; its tendon is inserted into the representative of the pisiform bone and also into the root of the rudimentary metacarpal bone beneath it: this is the "*flechisseur oblique du canon*" of Bourgelat.

The *extensor carpi ulnaris* (*cubito-sus-metacarpien*) arises from the posterior part of the external condyle of the humerus, and is inserted, like the preceding, into the os pisiforme, whence it is prolonged beneath the carpus, so as to perform the office of a flexor of the wrist ("*flechisseur externe*" Bourgelat.)

The *palmaris longus* does not exist in the Solipeda; nor is it found in the Pachydermata and Ruminantia, being in these orders of quadrupeds apparently combined with the flexor sublimis digitorum, as is likewise the case with this muscle in the bear, the badger, and the dog; in all other unguiculate quadrupeds it is disposed as in the human subject.

Muscles of the hand. — The *extensor communis digitorum* (*epicondylo-sus-phalangettien commun*). — This muscle in the horse is called by Bourgelat "*l'extenseur anterieur du pied*," and by Lafosse, "*l'extenseur du pied:*" it arises from the external condyle of the humerus and from the contiguous fasciæ, also from the upper and lateral part of the radius; its fleshy belly is strong, and terminates in a single tendon, which runs over the foot to be inserted into the last phalanx or coffin-bone, having previously given off a slip to join the tendon of the extensor minimi digiti.

Fig. 502.



Myology of the Horse. (*After Stubbs.*)

Head. — *a*, Orbicular muscle of the mouth; *g*, elevator of the chin; 5, arteria angularis; 6, arteria temporalis.

Neck. — *t*, Obliquus capitis inferior; 7, ligamentum nuchæ.

Trunk. — *m*, Transversalis abdominis; *t*, sphincter ani.

Left anterior Extremity. — *w*, Insertion of brachialis anticus; *d*, flexor profundus digiti; *p*, flexor carpi radialis; *u*, ligaments of the carpus; *l*, *m*, tendon of the flexor sublimis perforatus.

Right anterior Extremity. — *l*, *m*, Tendon of the flexor sublimis; *i*, insertion of flexor profundus into the coffin bone; *r*, flexor brevis digiti pedis.

Left posterior Extremity. — *p*, adductor magnus femoris; 7, vastus internus; *u*, gracilis; 13, 15, plantaris; 28, flexor longus digiti pedis; 16, external malleolus; 17, Internal malleolus; 18, division of the tendon of plantaris, to allow the tendon of the flexor profundus to proceed to its insertion at 31, into the coffin bone; 11, flexor brevis digiti pedis; 36, obturator artery; 37, nerves to the tibialis anticus.

Right posterior Extremity. — *c*, Tranversalis penis;

f, glutæus internus; *b*, iliacus internus; 10, vastus internus; 33, sciatic nerve; 23, poplitæus; 25, 26, tibialis posticus; 28, 29, 30, 31, flexor longus digiti pedis; 24, poplitæal nerve; 38, posterior tibial nerve; 40, articular ligaments of the knee ankle and pastern joints; 26, insertion of the tendon of the tibialis posticus into 29, that of the flexor longus digiti pedis; 11, flexor brevis digiti pedis; 31, insertion of the tendon of the flexor longus into the coffin bone; 41, internal cartilage of the hoof.

The *extensor proprius minimi digiti.* — In the horse this muscle is represented by two muscles. One of these, called by Bourgelat the *lateral extensor of the foot*, and by Lafosse *the extensor of the pastern*, is inserted by the intervention of a strong tendon into the side of the first phalanx of the solitary toe that forms the foot. The second muscle, placed between the above and the preceding muscle, furnishes a similar tendon, which, after passing in front of the carpus, becomes united at an acute angle with that of the former, the two co-operating with each other in extending the foot.

In the Ruminantia likewise this muscle is disposed after two different manners. In the Cervidæ or deer tribe, in which the rudimentary toes are capable of distinct movements, it furnishes two tendons to the two outer toes; whilst in oxen, goats, sheep, and antelopes its tendon presents a double insertion — one into the posterior aspect of the outer finger, the other into the tendon of the extensor communis.

The *extensor proprius indicis* and the two long extensors of the thumb are, in all the ungulate quadrupeds, entirely wanting.

The *abductor longus pollicis* is present in all the mammalia, even in the Ruminantia and the Solipeds. In the horse its tendon is implanted into the internal surface of the base of the cannon bone, so that it thus becomes an extensor of the foot (*l'extenseur oblique du canon* of Bourgelat).

The *flexor digitorum sublimis perforatus* and the *flexor profundus perforans.* — In the horse these muscles arise in common from the internal protuberance of the os humeri, and the two are confounded together for a considerable distance, when the two muscles separate to form two distinct tendons; of these, that belonging to the flexor sublimis runs beneath the annular ligaments of the carpus, to be inserted into the base of the great pastern bone previously dividing to give passage to the tendon of the profundus on its way to be implanted into the last phalanx or coffin bone of the foot.

In the ungulata the *small muscles of the hand* would evidently be useless, and accordingly in the horse all traces of them are lost, their place being supplied by the peculiar structure of the foot, to be described further on.

Posterior Extremity — Muscles of the Pelvis. —The muscles specially belonging to the pelvis are the *quadratus lumborum* and the *psoas parvus*, which in quadrupeds offer precisely the same arrangement as in man.

Muscles inserted into the os femoris —These are similarly disposed in all the Mammifera possessed of a pelvic extremity, the only differences observable being in their proportionate sizes. In the Solipeda the analogue of the *glutæus maximus* is so small, in comparison of the two other glutæi, that it is named by Bourgelat "*le petit fessier*," and by Stubbs the *glutæus externus*. In the human subject the comparative large size of this muscle is rendered necessary in consequence of the erect attitude of the body, which it principally assists in maintaining; whilst in quadrupeds, from the horizontal position of their bodies, it becomes of very secondary importance. In the horse it is a comparatively slender muscle, deriving its principal origin from the sacral fascia, but also reinforced by a long slender fasciculus, which descends immediately from the upper portion of the ileum. Its insertion is into the third trochanter and external rough surfaee at the upper part of the thigh bone, and also by strong tendinous aponeuroses into the fascia lata.

The *Glutæus medius* is the principal muscle in this region; it arises extensively from the sacro-iliac aponeurosis, and from the external surface of the ileum, from which origin it runs downwards and forwards to be implanted into the outer surface of the great trochanter, and is, moreover, prolonged, by means of a strong posterior fasciculus, towards the lower extremity of the femur. From this latter circumstance, as well as from its preponderating strength, the glutæus medius may be regarded as being, *par excellence*, the kicking muscle in these quadrupeds which instinctively have recourse to this mode of defence as best suited to their organization.

The other muscles inserted into the great trochanter — namely, the *glutæus minimus*, the *quadratus femoris*, the *obturator externus*, the *obturator internus*, the *gemelli*, and the *pyramidalis* — present in all quadrupeds a disposition similar to that which they have in the human body.

The muscles passing between the pelvis and the lesser trochanter, and also those that arise from the pubis to be implanted into the internal surface of the thigh, in the generality of quadrupeds, correspond very accurately with those of man. In the horse these are the *psoas magnus*, the *iliacus*, the *pectinæus*, and the *triple adductor*, none of which offer any peculiarity worthy of remark.

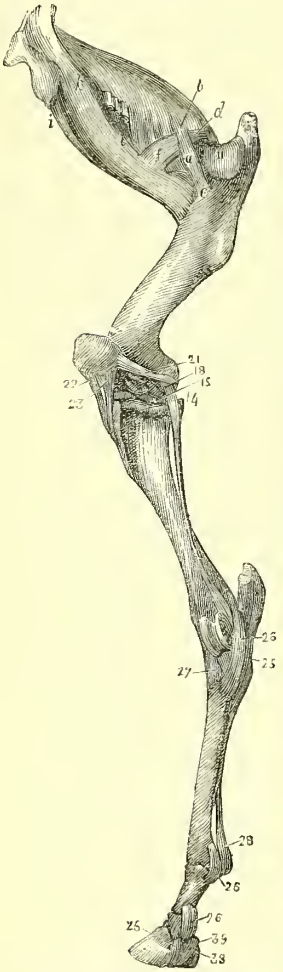
The *flexor muscles of the leg* are the *biceps flexor cruris*, the *semimembranosus*, the *semitendinosus*, the *sartorius*, the *gracilis*, and the *poplitæus*, all of which are enclosed by the dense fascia of the thigh, or fascia lata, which is kept tense by the action of a special muscle named the *tensor vaginæ femoris*.

The last-named muscle, called also the *musculus fasciæ latæ* (*ileo-fascien*) arises in the horse from the anterior portion of the crest of the ileum, whence it descends obliquely downwards, enclosed between two layers of the fascia, covering the thigh, into which it is strongly inserted.

The *extensor muscles of the thigh* — viz. the

biceps (*ileo-rotulien*), the *vastus internus*, the *vastus externus*, and the *cruralis* — offer in all quadrupeds the same general disposition as in man, the three last forming one great common muscle (*trifemoro-rotulien*). The anterior margin of the thigh in the horse and in other quadrupeds is formed by the *sartorius* (*ileo-pretibien*), which here, from its position and office, has been named by hippotomists the "*long adductor of the thigh*."

Fig. 503.



Deep muscles of the thigh and ligaments of the posterior extremity of the Horse.

a, *b*, *c*. A muscle named by Stubbs "*musculus parvus in articulatione femoris situs:* it arises by a flat tendon (*b*), from above the tendon of the *rectus cruris* (*d*), and is inserted tendinous into the os femoris (*c*); *i*, *k*, *l*, *iliacus internus*. The small numerals indicate the principal ligaments of the limb.

The *biceps* (*ischio-peronien*) in the horse and the greater number of quadrupeds, not even excepting the quadrumana, arises by a single origin, which is derived from the ischium, and the neighbouring ligaments and fascial expansions. This muscle covers a large proportion of the outer surface of the thigh: its principal insertion is into the head of the fibula, but it likewise throughout its whole length contracts extensive and important attachments with the fascia lata, so that it also becomes a powerful extensor of the thigh. There is moreover, in the horse and in the Ruminantia, a distinct portion of the biceps derived from the sacro-sciatic aponeurosis, the fibres of which are directed obliquely from before backwards, which, meeting the ischiatic portion at an angle, form with it a kind of raphe, which is prolonged for some distance. This muscle is called by Bourgelat the "*vastus longus*" of the thigh.

The *gracilis* (*pubio-pretibien*) is in all quadrupeds a very considerable muscle, more especially in such as have the thigh much shortened, as is the case in the horse, and the ungulata generally. It is called by Bourgelat the "*short adductor of the thigh*," whilst he gives the name "*gracilis*" to the semitendinosus.

The *semimembranosus* (*ischio-sous-tibien*) and the *semitendinosus* (*ischio-pretibien*) have in all quadrupeds the same origin and general arrangement as in man; but both of them are in the lower animals inserted into the tibia by a broad aponeurosis. It must also be remarked that their insertion extends much lower down than in the human subject, a circumstance which causes the leg to be permanently kept in a semiflexed condition; and is one of the great obstacles to their walking in an upright position. Even in the Quadrumana these muscles have their insertions very low down in the leg.

The *poplitæus* has nothing remarkable in its disposition.

Muscles implanted into the foot. The *gastrocnemii* (*bi-femoro-calcanien*) and the *solæus* (*tibio-calcanien*) are less considerable muscles, as regards their comparative size in quadrupeds, than in the human race: nevertheless their general disposition is invariably the same as in man. In the *Solipeda*, the *solæus* is remarkably slender and feeble.

The *plantaris* (*femori-calcanien*). — In the Solipeds this muscle is remarkably developed, so much so indeed as apparently to represent the flexor sublimis. In the horse this muscle arises under the external head of the gemellus from a large fossa in the os femoris above the external condyle: its tendon is continued downwards, and runs over the extremity of the os calcis, where it is enclosed in a sheath formed by strong ligaments, which prevent it from slipping out of its place; passing on from this point, it divides, to be inserted upon each side of the posterior surface of the great pastern bone towards its inferior extremity, here giving passage between its two insertions to the tendon of the long flexor of the toe, which it serves to bend down closely to the pastern when the fetlock joint is bent, thus seeming to perform the functions both of the *plantaris* and of the short flexor of the toes.

The *tibialis anticus*. — In the Ruminantia and in the Solipeds, the *tibialis anticus* is im-

planted into the anterior surface of the base of the metatarsal or cannon bone, so as to be simply an extensor of that portion of the foot which in these animals is usually misnamed the leg.

The *tibialis posticus* is altogether wanting in the Solipeds, as also in the Ruminantia and the hog-tribe.

The three *peronei* are, in the horse, represented by a single muscle, the tendon of which becomes conjoined with that of the long extensor of the digit, with which, when in action, it co-operates.

Muscles inserted into the digit. — The abductors and adductors * are the *abductor pollicis*, the *adductor obliquus pollicis*, the *adductor transversalis*, the *abductor minimi digiti*, and the *interossei.*

The *flexor muscles* in the horse are necessarily reduced to a state of extreme simplicity ; the short flexor communis is entirely wanting ; the *plantaris*, as described above, considerably increased in importance, has a double insertion into the base of the great pastern bone, and presents a similar disposition to that of the flexor perforatus in digitate quadrupeds, while the *flexor communis longus perforans*, here reduced to a single tendon, appropriated to the solitary toe, passes on as usual to be inserted into the last phalanx.

The *flexor longus pollicis* exists both in the Ruminantia and Solipeda, notwithstanding the total absence of a thumb in these animals ; but, instead of its usual destination, it here becomes affixed to the tendon of the flexor communis perforans, to which it forms a powerful auxiliary.

The *extensor muscles* of the toes in all digitate quadrupeds, provided with a representation of the great toe in the human foot, resemble those of man : in other animals there are some peculiarities that require notice. In the Quadrumana, the three muscles found in the human foot are present ; but in addition to these there is a proper *abductor of the thumb* (*adductor*, as it would be called by the anthropotomist), situated upon the inner side of the extensor pollicis longus, of which no traces exist in mankind.

Where the inner toe is wanting, as in the dog and the rabbit, the extensor pollicis is likewise deficient.

In the cloven-footed quadrupeds there is a proper extensor to the inner toe representing that of the thumb, and the peroneus longus, which is inserted into the external toe, performs the office of extending that also : there is moreover in Ruminants a long abductor of the thumb, the tendon of which is inserted close to that of the tibialis anticus

In the Solipeds, the *extensor communis* (*peroneo-sus-onguien*) terminates in a single tendon, which is inserted into the dorsum of the last phalanx of the foot : it receives, however, in transitu, a few fleshy fibres derived from the cannon bone, which represent the *extensor brevis* of unguiculate quadrupeds.

In the Solipeda, as might be expected, the *abductors and adductors* of the toes are entirely wanting.

Muscles which act immediately upon the lower jaw. — These are the *masseter*, the *temporal*, and the two *pterygoidei*, which in all quadrupeds have the same general arrangement as in human beings.

Muscles of the os hyoides. — The os hyoides of the Solipeds is constructed in accordance with a plan common to the Ruminants, and many Pachydermatous quadrupeds. Its body is arched and broad, presenting in the middle of its fore part a simple tubercle, and a tolerably long apophysis. It is consolidated with the superior cornua, which together form a very open arch. The single piece forming the anterior cornu is articulated to a rounded tubercle, situated just in front of the union between the posterior cornua and the body of the os hyoides, so as to admit of a considerable degree of motion in this joint. At its termination it is connected to the styloid process, which is very long and slightly forked.

The movements of the os hyoides are effected by numerous muscles, derived from several sources, the general arrangement of which, in most quadrupeds, conforms pretty nearly with what occurs in the human species.

The *sterno-hyoideus* exists in all quadrupeds, or, at least, is represented by a muscle of correspondent effect, derived from the sternum. In the Solipeda and in Ruminants, the sterno-hyoideus and the sterno-thyroideus form but a single muscle, which divides, to be inserted into both the larynx and os hyoides.

The *omo-hyoideus* in the horse is a very strong muscle, resembling in its origin that of the human subject ; but in some ruminants, as, for example, in the sheep, the analogue of the omo-hyoideus is derived from the transverse processes of the inferior cervical vertebræ.

The *genio-hyoideus* and the *mylo-hyoideus* have nearly the same arrangement in all mammiferous quadrupeds.

In the horse, all three of the above muscles are present. The *stylo-hyoideus* furnishes a sheath to the longer portion of the digastricus, and extends from the furcate extremity of the styloid bone to the base of the posterior corner of the os hyoides : this is the " *grand cerato-hyoidien* " of Gerard. There is also a " *cerato-idien lateral* " (*cerato-hyoideus*) of Girard, extending between the corner of the os hyoides and that of the thyroid cartilage.

Thirdly, there is the *mastoido-styloideus* (*stylo-hyoidien* of Gerard), a short thick muscle, derived from the long pyriform apophysis of occipital bone, whence it descends towards the angle of the styloid bone, into

* In comparative anatomy, owing to the permanently prone condition of the hand and foot of animals, it is impossible to employ the terms abductor and adductor, external and internal, &c., in the same sense as the anthropotomist : by *abductors* we therefore mean muscles which separate the external from the middle fingers, by *adductors* those which bring the fingers more closely together.

which it is inserted, above the origin of the stylo-hyoideus.

The other muscles of this region exhibit no peculiarities worthy of notice.

The muscles of the tongue, of the palate, and of the larynx, are in most quadrupeds strictly comparable to those of the human species.

Muscles of the Face. — These, from the conformity of their general arrangement with what exists in man, are distinguishable by the same names as are employed in human anatomy.

Fig. 504.

Facial Muscles of the Horse. (*After Sir Charles Belt.*)

a, orbicularis palpebrarum; *b, d*, cutaneous slips which raise the outer and the inner commissures of the eyelids; *c*, depressor of the lower eyelid; *e*, zygomaticus; *f, g*, levator anguli oris alæque nasi; *h*, elevator of the upper lip; *i*, dilator narium; *k*, nasal cartilage; *l, m*, orbicularis oris; *n*, masseter.

The *epicranius*, or *occipito-frontalis*, exhibits the usual origin from the posterior part of the cranium, whence, running forwards, it covers the skull with its tendinous aponeurosis, and, in front, spreads in muscular slips upon the forehead, some of which (*fig.* 504. *l*) extend downwards, to spread over those of the orbicularis palpebrarum.

Situated upon the outer side of the orbit there is another descending slip of muscle (*fig.* 504. *d*), apparently derived from the lateral muscle of the cartilage of the ear which, by elevating the external canthus of the eye, contributes much to the expression of that organ.

The *orbicularis palpebrarum* (*fig.* 504. *a a*) arises, as in the human subject, from the commissural ligament at the inner canthus of the eyelids, whence it winds round the orbit, its lower fibres receiving attachment from the os lachrymale.

Internal to the last-named muscle are a few fibres, that represent the *corrugator supercilii.*

The *Levator anguli oris* (*fig.* 504. *f, g*) is, likewise, extensively inserted into the upper lip and margin of the nostril: it has two origins, derived from the surface of the superior maxillary bone, between which the lateral dilator of the nostril and upper lip passes to its destination.

The *depressor of the lower eyelid* (*fig.* 504. *c*) is a short muscular slip, the use of which is sufficiently indicated by its name.

The *zygomaticus* (*fig.* 504. *e*) is a depressor of the external angle of the eye, as well as an elevator of the corner of the mouth, its fibres being intermixed with those of the orbicularis palpebrarum, as well as of the orbicularis oris.

The *long dilator of the nostril, and elevator of the upper lip* (*fig.* 504. *i*), arises at a little distance below the inferior margin of the orbit; and, passing between the two origins of the levator anguli oris, terminates in a tendon, which becomes connected with that of the opposite side, and then spreads out in front of the upper lip.

From the tendon of the last muscle arises the *anterior dilator of the nostril* (*fig.* 504 *h*), which, acting upon the interior nasal cartilage, powerfully expands the aperture of the nose.

The other muscles — viz. the *orbicularis oris*, the *levator labii superioris*, the *elevator of the chin*, and the *depressors of the lower lip, and angle of the mouth* — need no particular description.

ALIMENTARY APPARATUS. *Teeth.* — The dental formula common to the Solipeda is as follows: —

Incisors $\frac{3-3}{3-3}$, canine $\frac{1-1}{1-1}$, premolars, $\frac{3-3}{3-3}$, molars, $\frac{3-3}{3-3}$. The canine teeth, however, it must be observed, only exist in the male sex.

The *incisor teeth*, in the generality of herbivorous quadrupeds, are bevelled off posteriorly, so as to present in front chisel-like cutting edges; but in the Solipeds, when young, the lateral incisors are furnished with two cutting edges, one in front and the other behind, from which circumstance those central fossæ are produced which, as we shall see further on, furnish important testimony relative to the age of the animal.

The *canine teeth*, here called "*tusks*," or "*tushes*," are always of very moderate dimensions, and their points, at an early age, become flattened and blunt. Those of the upper jaw are separated from the incisors by a con-

siderable interval; and a similar interspace also exists, but to a less extent, in the lower jaw.

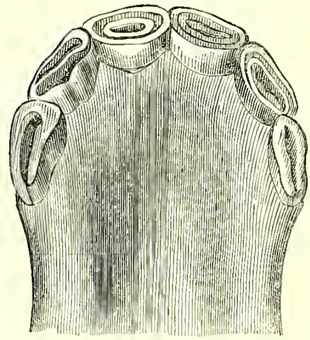
The *molar teeth* of the horse are of a prismatic form, their grinding surfaces being marked with four crescents of enamel in the lower jaw, and with five in the upper: these crescentic patches in the upper jaw have their concavities turned outwards, but in the lower jaw in the opposite direction. The teeth of the horse are, moreover, distinguishable from those of the ox and some other Ruminants, which they resemble in their general appearance, from the circumstance that, in the latter, the crescentic patches of enamel are arranged in pairs, and are placed parallel to each other; whilst in the horse they are situated alternately, the first of the inner margin of the tooth corresponding to the interval between the two of the outer margin.

Professor Owen * observes, that the character by which the horse's molars may be best distinguished from the teeth of other Herbivora corresponding with them in size, is the great length of the tooth before it divides into fangs. This division, indeed, does not begin to take place until much of the crown has been worn away; and thus, except in old horses, a considerable portion of the whole of the molar is implanted in the socket by an undivided base. The deciduous molars have shorter bodies, and sooner begin to develope roots; but in these, or in an old permanent molar with roots, the pattern of the grinding surface, though it be a little changed by partial obliteration of the enamel folds, yet generally retains as much of its character as to serve, with the form of the tooth, to distinguish such tooth from the permanent molar of a Ruminant.

A knowledge of the structure and history of the teeth of the horse becomes additionally important, from the circumstance that it is from the condition of the dental apparatus that an estimate may be formed concerning the age of the animal; and, in order to understand the data thus afforded, it will be necessary to consider the structure of these organs rather more closely.

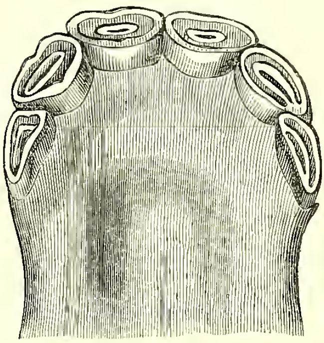
The incisors †, when the permanent teeth are first completely developed, are arranged close together, forming the arc of a circle at the extremity of both jaws; they are slightly curved, with long simple sub-trihedral fangs, tapering to their extremity. The crowns are broad, thick, and short; the contour of the biting surface, before it is much worn, approaching an ellipse. These teeth, if found detached, recent, or fossil, are distinguishable from those of the Ruminants by their greater curvature, and from those of all other animals by a fold of enamel, which penetrates the body of the crown from its broad flat summit, like the inverted finger of a glove. When the tooth begins to be worn, the fold forms an island of enamel, inclosing a cavity partly filled with cement, and partly by the discoloured substances of the food, and is called "*the mark.*" In aged horses the incisors are worn down below the extent of the fold, and "the mark" disappears. The cavity is usu-

Fig. 505.



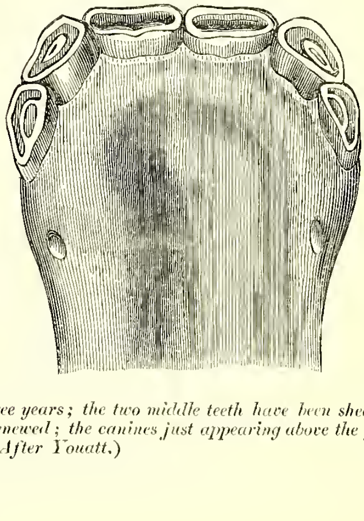
Lower jaw of a one-year-old Colt; milk incisors. (After Youatt.)

Fig. 506.



Two-years'-old; milk incisors, middle pair much worn. (After Youatt.)

Fig. 507.

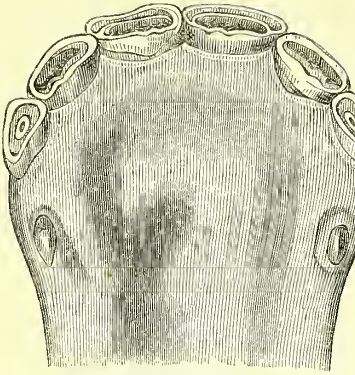


Three years; the two middle teeth have been shed and renewed; the canines just appearing above the gums. (After Youatt.)

* Odontography, p. 574.

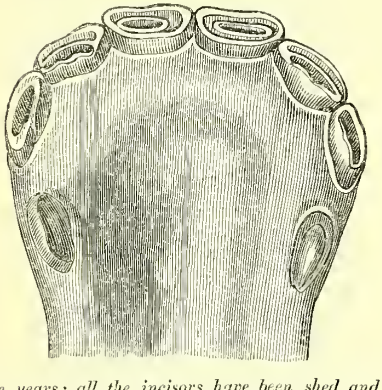
† Owen, Odontography, p. 572.

Fig. 508.



Four years; four teeth have been shed and renewed. (*After Youatt.*)

Fig. 509.



Five years; all the incisors have been shed and renewed; the middle pair much worn. (*After Youatt.*)

ally obliterated in the first, or mid-incisors, at the sixth year; in the second incisors at the seventh year, and in the third, or outer incisors, in the eighth year, in the lower jaw. It remains longer in those of the upper jaw, and in both the place of the "mark" continues for some years to be indicated by the dark-coloured cement, even to about sixteen years old. At this period the worn summits of the incisors present a subtriangular form.

The canine teeth are small in the horse, and rudimentary in the mare; the unworn crown is remarkable for the folding in of the anterior and posterior margins of enamel, which here includes an extremely thin layer of dentine. The representative of the first premolar in the first set of teeth is a very small and simple rudiment, and is soon shed. The three normal premolars are as large and complex as the true molars, the anterior one being usually the largest of the series in the upper jaw.

Salivary Glands. — The salivary apparatus in the Solipeda is very extensive, perhaps more so than in any other class of quadrupeds, consisting of large glandular masses divided into numerous lobes and lobules of a pale colour, and but loosely connected together by cellular tissue.

The *Parotid Glands* in the horse constitute a secreting apparatus, the bulk of which is extremely remarkable. Each of these glands extends from the external meatus auditoreus along the side of the head and of the lower jaw, as far forwards as the masseter muscle, and at the same time stretching deeply inwards as far as the side of the trachea. This enormous glandular organ may be considered as composed of three principal portions: each furnishing its excretory duct, which, however, soon unite to form a common canal, which at first descends within the angle of the jaw, whence, winding round the anterior edge of the masseter, it mounts up externally as far as the buccinator musele, which it perforates nearly opposite the fourth molar tooth of the upper jaw, its internal orifice being situated in the centre of a prominent papilla.

The *Submaxillary Glands* are much smaller than the parotids. Posteriorly they consist of a thick globular portion, which is adherent to the inner surface of the parotid, but as they advance forwards, they become considerably attenuated, each terminating in its appropriate duct. The latter is of considerable length, and, after passing the sublingual gland, with which it contracts some attachments, opens into the mouth at a little distance behind the canine tooth, its opening being in the immediate vicinity of a papilla that seems to form a kind of valve at its orifice.

The *Sublingual Glands* are smaller than the preceding, and are of an oblong shape: they pour the saliva that they secrete into the cavity of the mouth through numerous orifices arranged in several rows on each side of the tongue.

In addition to the above large glandular organs, there remain to be noticed the *Molar Glands*, consisting of numerous detached granular-looking bodies of a lenticular shape situated beneath the mucous membrane that lines the buccinator muscle, and the inner surface of the superior maxillary bone behind which they mount up into the zygomatic fossa to within a little distance of the abductor muscle of the eye.

Pharynx. — The pharynx in quadrupeds generally presents a structure very similar to that of the human race, and may be said to be composed of analogous muscles: nevertheless its horizontal position in these animals renders the necessity for muscular exertion during deglutition greater than in man; and, accordingly, these fibres are not only stronger in quadrupeds than in our own persons, but sometimes additional muscles are met with, by the aid of which the action of swallowing is facilitated.

In the horse, the muscle which represents the *middle constrictor of the pharynx* might more properly be called the *pterygo-palato-*

pharyngeus *, its fibres descending from the pterygoid and palate bones, along the sides of the pharynx, around which they wind obliquely, uniting in the middle line upon its posterior surface, where they form a thick muscular layer.

The *inferior constrictor*, or *thyro-pharyngeus*, is equally broad and strong, its fleshy fibres taking nearly the same direction as they proceed towards the back of the pharynx, where they join by a median raphe.

In addition to the above, there is a *crico-pharyngeus*, arising from the posterior and inferior margin of the cricoid cartilage, whence its fibres extend obliquely upwards along the sides of the pharynx.

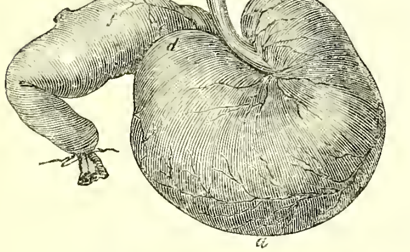
The analogue of the *stylo-pharyngeus* is, in the Solipeds, a cylindrical muscle derived from the styloid bone, and, running from behind forwards upon the sides and upper part of the pharynx, mixes its fibres with those of the superior constrictor — its action is to raise the commencement of the pharyngeal sac, which it at the same time dilates and draws backward.

There is likewise a small muscle derived from the middle part of the styloid bone, the fibres of which run backwards and inwards, so as to meet those of the muscle last mentioned.

Lastly, there are two other muscles, the fibres of which take a longitudinal direction. One of these, the *pharyngeus proprius*, arises from the tendinous middle line that extends from below the insertion of the stylo-pharyngei, and is prolonged downwards along the posterior and lateral walls of the œsophagus: the other, the *aryteno-pharyngeus*, is a small muscular band proceeding from the back part of each arytenoid cartilage, and running down the front of the œsophagus towards the stomach.

Stomach. — In all the Solipeda the stomach is simple, and presents little remarkable in its shape. The œsophagus (*fig.* 510. *b*) is inserted at a very acute angle into its smaller curvature, which is, as it were, folded upon itself. The cardiac cul-de-sac (*c*) is very capacious,

Fig. 510.



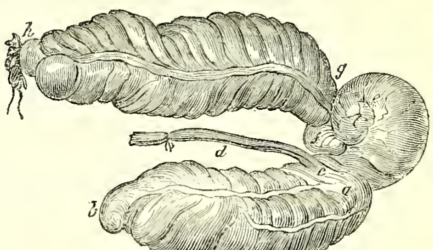
Stomach of the Horse.

and is lined throughout internally with a thick cuticular layer continuous with the lining of the œsophagus, and extends nearly as far as the middle of the stomachal cavity, where it terminates abruptly by a prominent indented edge, the interior of the pyloric half of the viscus (*a*, *d*) presenting the usual villous mucous surface. The muscular coat of the stomach consists of several superimposed layers of fibres that cross each other in different directions, some of them being apparently derivations from the muscular bands of the œsophagus; and it is doubtless the contractions of these muscular bands, in conjunction with the obliquity of the entrance of the œsophagus, that renders the act of vomiting impossible in these animals.

The alimentary canal in the Solipeds is short in comparison with that of the Ruminants and some other herbivorous quadrupeds; but this want of length is perhaps more than made up for by the enormous capacity of the large intestine, which, on first opening the body of one of these animals, seems of itself to occupy the whole of the abdominal cavity.

Commencing from the pylorus, the duodenum (*fig.* 510. *f*.) is found to be considerably

Fig. 511.



Caput Coli &c. of the Horse.

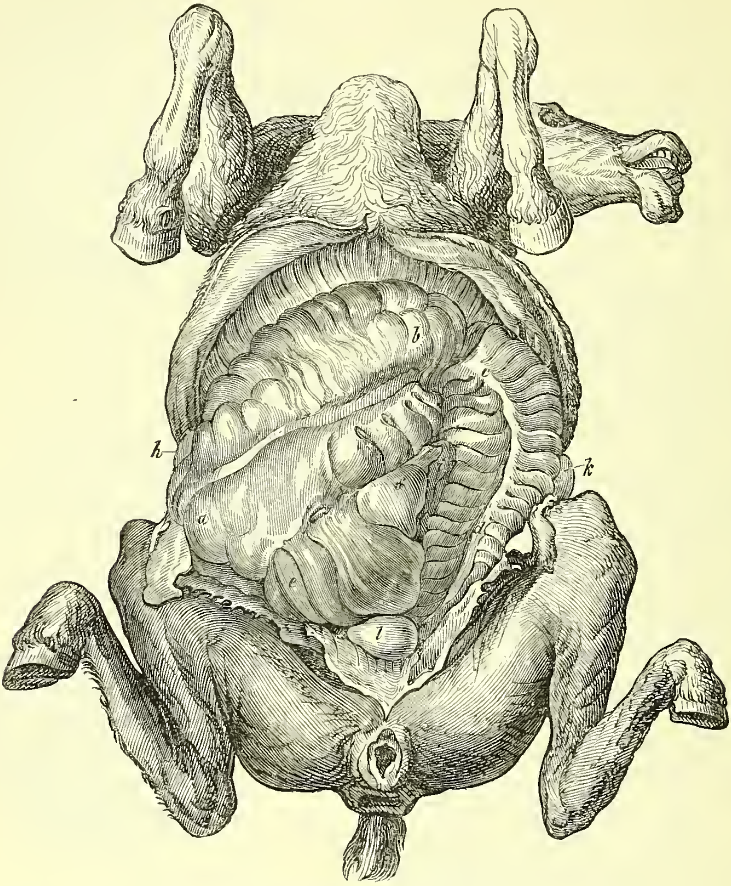
dilated; but its diameter soon contracts, and the rest of the tract of the small intestines is of pretty equable dimensions throughout, or if it presents constrictions here and there, they disappear when the gut is distended with air. The iliac portion of the small intestine (*fig.* 511. *d*) terminates in a cæcum of enormous bulk (*fig.* 511. *a*, *b*, *c*, *c*, *f*), which is separated from the commencement of the colon by a deep constriction (*g*): the colon itself is throughout its entire extent proportionately voluminous, commencing in the right flank: its ample folds (*fig.* 512. *a*, *b*) mount upwards as far as the diaphragm, whence they descend again, forming a viscus of vast capacity as far as the left iliac region, where, becoming gradually contracted in its dimensions, it terminates in the rectum. The ascending portion of the colon (*a*, *b*) is separated from the descending part (*c*, *d*) by a constriction; and the latter forms a third remarkable dilatation before it ends in the rectum. The whole colon is puckered up into huge sacculi by three longitudinal muscular bands, which

* Cuvier, Leçons d'Anatomie Comparée, tom. iv. p. 606.

terminate where the rectum begins, the last-named division of the alimentary canal presenting only a few pouches of comparatively small size, in which the fæces become moulded into balls preparatory to their expulsion.

When in a state of moderate distension, the

Fig. 512.



Colon of the Mare in Situ.

small intestines of an ordinary size are found to measure about fifty-six feet in length from the pylorus to the cæcum, with a circumference varying according to the state of contraction of the bowel from two inches and a half to six inches. The cæcum is about two feet and a half long, and about two feet in circumference at its broadest part; but towards its blind termination it assumes a conical form, and terminates in a point (*fig.* 511. *b*). Above the ileo-cæcal junction, the intestine forms a cul-de-sac (*fig.* 511. *e*), which is bent upon itself so as almost to resemble a second cæcum separated from the rest of the colon by a deep contraction, and there is, moreover, sometimes a third globular cavity, situated as shewn in *fig.* 511. *f*: but this is not constantly present.

The enormous colon (*fig.* 512. *a*, *b*, *c*, *d*), which seems of itself to occupy the whole abdominal cavity, is divided into two portions: — the first (*a*, *b*) is about 2 feet 3 inches long, and, at least, two feet in circumference; the second portion (*c*, *d*) is of nearly the same dimensions; but towards its termination, its circumference diminishes to 10 inches, and the continuation of the bowel retains that size for the length of a couple of feet, when it again enlarges to a circumference of 2 feet 4 inches before its termination in the rectum.

The entire length of the colon and rectum taken together is 21 feet, which, added to the length of the small intestines, gives a total length of 77 feet for the intestinal canal, exclusive of the cæcum.

Liver. — This viscus in the horse is divided pretty equally between the left and the right sides of the body. It is divided into four lobes, measures about a foot and a half in its greatest diameter, and weighs between four and five pounds. There is no gall-bladder; but the hepatic duct is extremely capacious, and evidently forms a receptacle for the biliary secretion.

Spleen. — The spleen of the horse has the shape of an elongated triangle, situated, ob-

liquely, upon the left side of the stomach; its base pointing upwards and backwards, and its apex downwards and forwards; it is about 9 inches long, 4 inches broad at its widest part, and three-quarters of an inch in thickness. Its weight is about twelve ounces.

The *pancreas* is of an irregular shape, appearing to be made up of three branches — the shortest of which terminates at the duodenum; of the other two, one extends beneath the right, and the other reaches as far as the left kidney: these three branches form, by their union, a flattened mass, about half an inch in thickness, which may be called the body of the pancreas. There is nothing remarkable in the arrangement of its excretory duct.

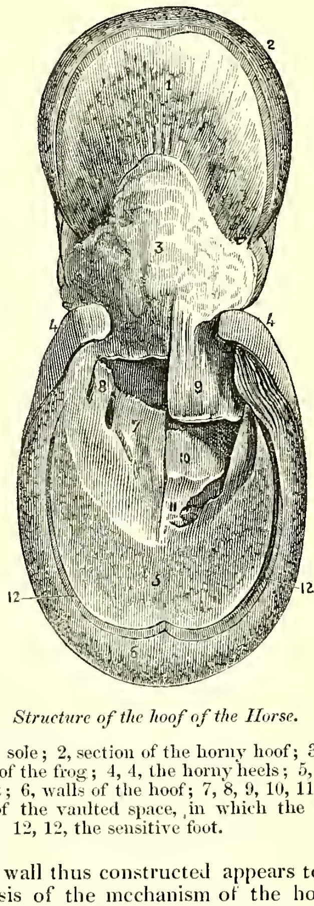
Circulatory Apparatus. — The structure of the *heart* and the general arrangement of the *arterial and venous systems* offer no peculiarities worthy of notice.

Structure of the Horse's Foot.—The mechanical structure of the foot of the horse demands to be considered at length, for in whatever point of view this part of their economy is regarded, either as a simple instrument of progression, or a curious piece of anatomy, it will be found equally deserving the study of the physiologist and of the veterinarian. Numerous writers have accordingly devoted their attention to this subject, both on the continent and in our own country; but their descriptions are, unfortunately, so mixed up with terms of farriery and stable jargon, that the anatomist finds considerable difficulty in deciphering their elaborate disquisitions. Among the most philosophical English treatises are those of Professor Coleman and Mr. Bracy Clark, to both of whom we shall be indebted for many of the following observations.

Horny hoof. — The whole exterior conical covering of the horse's foot, called in technical language the "wall of the hoof," is formed of a dense horny substance, which in shape resembles a hollow cone obliquely truncated at its upper part, so that the hoof is deepest or highest in front of the foot, diminishing in this respect as it recedes backwards towards the "quarters;" it then loses, to a considerable extent, its conical shape, and becomes nearly upright, especially on the inside or inner quarter, still growing narrower or lower to the posterior extremity of the foot, where, at first sight, it appears to terminate by mixing with the substance of the "frog," hereafter to be described, and with the integuments of the posterior region of the foot: instead of terminating in this manner, however, a more accurate examination shows it to be suddenly inflected inwards, pursuing its course towards the centre of the foot, where, diminishing gradually in depth, it is finally lost, becoming mixed up with the "sole," near the point of the frog, thus forming a distinct and remarkable internal wall that supports the under parts of the foot, and at the same time protects, by its bold projection, the sole and the frog from an undue degree of pressure and contusion against the ground.

The parts thus formed by a continuation of the wall of the hoof beneath the foot, are called the "*bars of the foot*," and are frequently described with, and taken for, part of the "sole." The direction of this sloping floor serves to throw all superincumbent pressure outwards towards the sides of the foot, and at the same time leaves a triangular space, posteriorly, for the insertion of the frog (*fig.* 513.), which it likewise protects from injury.

Fig. 513.



Structure of the hoof of the Horse.

1, the sole; 2, section of the horny hoof; 3, upper surface of the frog; 4, 4, the horny heels; 5, Bars of the foot; 6, walls of the hoof; 7, 8, 9, 10, 11, boundaries of the vaulted space, in which the frog is lodged; 12, 12, the sensitive foot.

The wall thus constructed appears to form the basis of the mechanism of the hoof, to which all the other parts are subordinate, and, if so understood, will much facilitate our views of the nature and economy of its structure. Its inner surface is every where lined, as it were, with numerous elastic lamellæ that project internally, and arranged in parallel lines, proceeding downwards perpendicularly towards the front of the foot (*fig.* 514, 3.): these horny laminæ are, at least, five hundred in number, and afford, from the aggregate surface that they present, a very extensive superficies for the attachment of an equal number of similar processes, derived from the vascular surface that covers the coffin bone, with which they interdigitate in such a way that the pressure to which the foot is subjected, which if concentrated upon a small surface would in-

evitably cause the destruction of living tissues, becomes so diffused as to produce no inconvenient results.

The horny lamellæ above alluded to, when removed from the hoof, have little or no elasticity when drawn in a longitudinal direction; but when drawn transversely, they possess this quality in a very remarkable degree, more especially in resisting pressure applied in a direction outwards and downwards, to resist which, the arrangement of their fibres is, on close examination, found to be particularly adapted.

The whole horny hoof, if unravelled by maceration or long continued exposure, is found to be essentially composed of longitudinal corneous threads or hairs matted, and, as it were, strongly glued together, — a structure preeminently adapted to combine all the requirements of strength, elasticity, and toughness.

As it approaches the quarters and heels, the horny helmet encasing the foot diminishes in its thickness as well as in height, affording, by this means, a degree of pliancy, which here becomes as necessary as firmness and unyielding solidity were in the front of the organ; yet, even here, by the doubling in of the hoof towards the sole, a strong horny margin is left, which is admirably adapted to receive the principal bearing of this part of the foot, and to protect and defend the sole enclosed within its curvature.

Frog. — The triangular chasm left by the inflections of the wall towards the centre of the foot, is filled up by a very remarkable organ, named, in the language of farriery, the "frog," either from some fancied gross resemblance which it bears to that animal, or, more probably, by corruption, from the French "fourche" or "fourchette," Anglicè "fork," applied to the same structure. By Latin writers, it is generally known under a similar appellation, "furca," and by the Greeks was named "χελιδονα," from a similarity between its shape and that of a swallow.

This body, which externally has the appearance of a triangular mass of elastic horn, may not be inaptly compared to an elastic key-stone received into an elastic arch communicating in some cases, and admitting in all, the springing movements of which such an arch would be capable. Its bar, which, towards the heels, is thin and broadly spread out, possesses a considerable degree of flexibility, which is gradually lost in approaching the centre of the foot, where there is less occasion for movement.

The *base* of the frog lies between and connects together the two posterior incurvations of the hoof; it then passes over and envelopes those parts, restraining their action. The *sides* of the frog are united by applied surfaces to the upper edge of the arch formed by the sole, or more truly the bar formed by the continuation of the wall. Its *point* extends to or beyond the centre of the sole.

The frog recedes from pressure in the natural foot, by having its level within the level of the other parts of the under surface of the foot, taking a third rate or degree of bearing upon the ground: the *wall* first; the *bar* next projecting beyond it: its base also retires further from pressure than the other parts of it, and is protected by the projecting angles of the *horny* or *lower heel*.

On either side, the frog is bounded by deep longitudinal excavations or channels, named the *commissures of the frog*; the bottom or deepest part of these channels, forming the line of union of the frog with the bar, a space is thus afforded on either side of the frog, which, as an elastic body, would have been useless without it; for in vain would elasticity have been given to any part, unless sufficient room was also given for its expansion. Towards the heels, these commissures are of considerable width, and they are there arched over by horny prolongation, from the base of the frog, named the *arch of the commissure.* The other extremity of the commissure growing, by degrees, shallower, is lost in the level of the sole, before it approaches the arch of the frog.

Seen from without, the frog makes a bold projecting appearance, as though it were a solid body of horn; and the smiths, deceived by this appearance, entertain but indifferent notions of its real structure, and use their paring knives upon it much more freely than its thickness warrants; for it is in reality only an inverted arch of horn that is turned downwards and reversed in respect to the general arch formed by the sole and bar, so that its real thickness in horn is by no means so considerable as on a first view it would appear to be.

Examined from within—that is to say, when the foot has been drawn forth from the hoof—the frog presents an inverted triangular arch, so intimately connected with the bar and sole, that no one would suspect it of being a distinct or divisible part, one uniform uninterrupted surface being everywhere observable on this inside: it may, however, be exhibited as a distinct inserted part by making a horizontal section of the foot through the union of the bar with the side of the frog, when the difference of their structure and appearance, and the line of their applied surfaces become sufficiently visible and distinct. A hoof exposed to the weather will also be seen in its decay to separate at this part first, and thus readily show its distinctness from the rest of the hoof.

In a perfect, well-formed foot, undistorted by shoeing, Bracy Clark observes that "the base of the frog occupies a certain division of the general circle of the hoof, and that this division is about a sixth part of the whole circumference. By knowing this fact we are not only led to entertain more just notions of the form of the foot and the proportions of its parts, but it affords us also an easy means of forming a pretty accurate guess of what injury or diminution the foot has sustained at any period of the life of the horse without previously seeing the original state of the frog."

The wings or lateral processes above described, as extending from the base of the frog, not only enclose the posterior ends or doublings in of the hoof, but the same horn is continued around the whole upper edge or margin of the roof, forming a broad convex band, whose upper edge, projecting higher than the hoof itself, receives and covers over the terminating edge of the skin, where it meets the hoof, and thus protects this part from external injuries, to which it would otherwise be liable. Posteriorly it is of considerable breadth, and firmly connects the frog with the upper part of the slope of the horny heels, over which it likewise expands. This structure, first described by Bracy Clark, received from him the denomination of the " coronary frog-band."

In the centre of the frog, as viewed from the sole, is a considerable cavity, the edges of which are furnished with rising lips or prominent margins of the horn ; this hollow is termed the *cleft of the frog*, and extends to a considerable depth. This cavity appears to serve the following useful purposes * : — 1st. It is a safeguard from rupture between the two halves or divisions into which the foot is almost separated. 2dly. By closing when pressure comes direct upon the underside of the foot, it prevents too much condensation of the horn at this part, and consequent pressure and a too solid resistance upon the soft parts beneath. 3dly. When the foot bears partially upon the ground, as by one side only, which will happen occasionally where the surface is irregular, it can extend along with that side of the foot without rupturing, by the greater liberty it thus affords to the part, while at the same time the strength of its margin secures it from laceration. 4thly. On loose soils this indent or cavity will doubtless assist in giving the foot a firmer hold by the irregularity it offers to the surface.

It is, however, upon the inner aspect of the hoof that the most remarkable part of this structure is to be observed, for when examined internally it is found that the external cleft is only the hollow base of a cone of stout horn of considerable size, which passes from it directly into the substance of the sensitive frog, and which, though completely imbedded in the soft parts, is nearly or quite as hard and tough as is the horn of the exterior of the frog which is exposed to the air. This remarkable provision seems to serve the purpose of uniting more firmly the two halves of which the foot of the solipeds at this part really consists, there being here an evident tendency, in the tegumentary defences of the horse's foot, towards that division which in the ruminating quadrupeds is completely carried out. This important cone of horn Bracy Clark named the *frogstay* or *bolt*, observing that, like an inserted tooth, it more firmly holds the horny to the sensitive frog, for while the sensitive frog falls into the inverted arch of the horny frog, and is thus held most firmly in its place, this part, entering in the opposite direction into the sensitive frog, serves reciprocally to confirm and fix these parts together, and preserve them from external injury and dislocation. An excellent view of this piece of anatomy is obtained by making a perpendicular section of the foot extending through the " heels and surrounding elastic matter."

* Bracy Clark, op. cit.

The Sole. — This is an irregular plate of horn, which serves to close up the space or great inferior opening described by the lower circumference of the wall, and makes the third member or part of the hoof. It is usually of an arched form, more or less flattened, its concavity being turned to the ground, so that its centre, which is the thinnest part, is by this means removed from the degree of external pressure which the sides or bottom part of the arch have to support.

Nature has secured herself, by the arrangement of this part, in two ways from the resistance which an arch of common properties would create on becoming condensed under pressure, and forcibly resisting the load brought upon it, which would have been subversive of the leading principles of the mechanism of the hoof. In the first place the sole being cleft to its centre or beyond it by the large triangular opening formed at its posterior part, which, destroying the resistance of the arch, serves to receive the ends also of the wall of the hoof first, and is then closed and filled up by the inverted arch of the frog ; so that the ends of the hoof are thus tied in and secured from being forced asunder by the pressure from within, being thus wedged in between the frog and the sole, serving in their places the other offices already noticed, while the sole, being thus broken, has a diminished resistance in the centre.

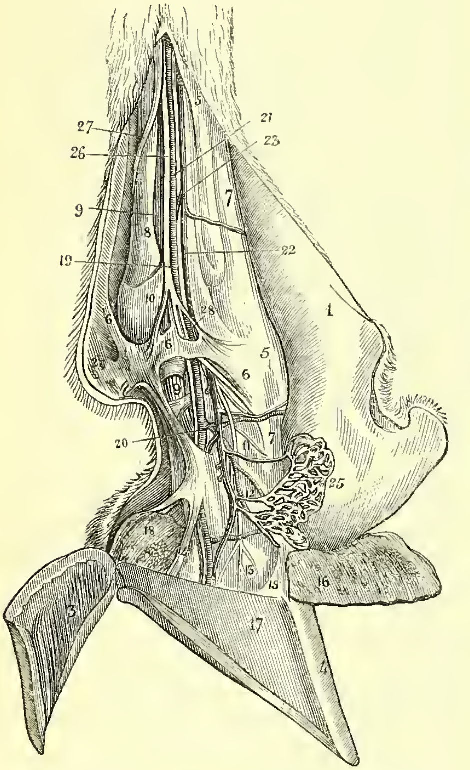
Again : the lower circumference of the arch of the sole is everywhere found abutting against the sides of the wall, which are rendered sufficiently flexible outwards to yield to the weight when pressed against by the descent and flattening of the sole, so that every provision for the elasticity of the foot is thus fully secured.

The horse's hoof is therefore fully provided with the means of preserving its form ; but this power is unfortunately grievously interfered with by the process of shoeing ; and it is in this country at least a very rare occurrence to obtain an opportunity of examining a foot in its full-grown natural condition.

From the above description of the foot of the horse it will be seen that, although when viewed in front it appears to be solid and single, the terms *Solidungula* and *Solipes* convey but a very imperfect notion of the real nature of this kind of hoof; for though the front be solid the posterior parts possess the greatest degree of elasticity, short of being actually cloven, that can be imagined from the sole being open to its centre and filled up with the frog. In such a foot as the term Solidungula would imply, or a continuous circle of horn, no animal could long stand, much less move, without great fatigue and pain from

compression, which would soon become destructive. If it were necessary to employ any single epithet to express the real nature of this kind of locomotive apparatus, Bracy Clark suggests that the term *Semifissipes*, or half-cloven foot, would be less objectionable, though also not exactly true, on account of the presence of the frog, which, added to the entire hoof in front, seems to afford the most essential character of this kind of foot.

Fig. 514.



Dissection of the superficial Parts of the Horse's Foot.

1, General integument; 2, fatty mass, forming a cushion behind the great pastern joint; 3, wall of the hoof turned back, showing the vertically lamellated horny processes projecting from its inner surface; 4, section of the wall of the hoof; 5, articulation between the cannon bone and the great pastern; 6, 6, 6, aponeurotic tissues; 7, 7, tendon of the extensor longus digiti pedis. 8, 9, 10, the flexor tendons of the foot; 11, 12, 13, 14, 15, expansions of the great anterior cartilage of the foot; 16, the coronary frog-band raised from the hoof; 17, the vascular or sensitive hoof; 18, elastic cushion of the heels; 19, 20, 21, arteria plantaris; 22, 23, plantar veins; 25, part of the coronary venous plexus raised from its position; 26, 27, 28, plantar nerves.

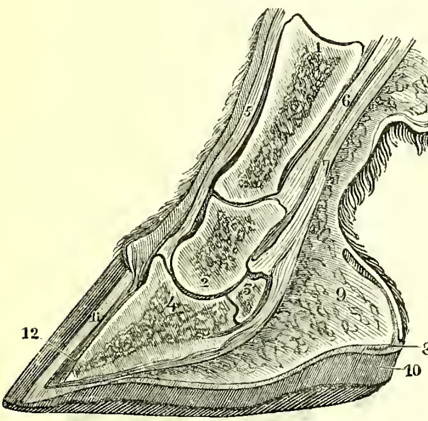
Cartilages of the Foot. — On removing the hoof there are seen immediately beneath it two large elastic cartilages ranging to a great extent along both sides of the foot. Their figure is almost too irregular for comparison; but, when seen on a lateral view of the foot, their shape may be said to resemble that of a lozenge or of a pretty fully expanded fan, fixed by its centre, which is very much thicker and more solid than the other parts, in a deep horizontal cavity or channel in the coffin bone provided for its reception; from this central point of insertion the anterior portion of it, passing forward, nearly meets the cartilage of the opposite side in front of the foot, the great extensor tendon of the foot only separating them, with which they are likewise connected, and make a common surface. On its inside this extremity of the cartilage takes a strong adherence to the condyles of the coronary bone, and so closely surrounds the joint betwixt the latter and the coffin bone that the articulation appears to be without any capsular ligament at this part. The posterior portion of the cartilage, ranging more largely and becoming thinner as it expands itself backwards, growing at the same time more elastic in its texture, is gradually and inseparably mixed up towards the hinder part of the foot with the skin and the ligamentary elastic tissues that form the "upper heels," and constitute the principal materials for elasticity in these parts. Spreading also in an upward direction to a considerable height above the hoof, it terminates by a rounded, thin, and irregular edge, which is inflected inwards over the soft interior of the foot, to which it forms a kind of roofing and defence.

Next, this widely distributed cartilage may be observed passing downwards, and surrounding on every side the rough and knotty extremities of the heels of the coffin bone, entering and filling up its sinuosities, and taking strong adherence to these processes; it then extends itself horizontally inwards, passing over the horny sole and bar, and, meeting the side of the sensitive frog, intimately unites with it, forming one inseparable mass, and together filling up the whole internal area described by the sides of the coffin bone. The upright or lateral portion of the cartilage forms, with this horizontal process inwards, a right angle, thus making together a hollow space or receptacle at the back of the coffin bone, that contains the spongy elastic stuffing of the heels, together with the tendons, trunks of bloodvessels, nerves &c., passing through this part to the sole of the foot. The upper surface of the horizontal process of cartilage is full of scabrous elevations and depressions that defy dissection, among which there exists a quantity of a gelatino-ligamentous material. Beneath, or to the under surface of this horizontal layer of cartilage, the sensitive sole and bar are adherent; and, in approaching the frog, or centre of the foot, it loses its cartilaginous nature, and becomes coriaceous, or rather ligamento-coriaceous, in texture, agreeing in this with the internal frog.

The horizontal portion or process of the cartilage, named by veterinary writers the "*straliform process*," is of greater thickness and substance than the other parts; it is also of a coarser grain and more elastic nature; both portions together communicate the gene-

ral boundary and form to the lateral, the posterior, and inferior parts of the foot; and when the bars or frog are thrust upwards by pressure from without, they are then acting against this same horizontal flooring, formed by the cartilage and the frog, and met by the depression of the bones of the foot forced down from the weight of the animal; the whole can then dilate exteriorly along with the posterior and more elastic parts of the hoof.

Fig. 515.



Longitudinal Section of the Foot of the Horse.

1, Great pastern bone; 2, lesser pastern or coronary bone; 3, sesamoid bone implanted in the flexor tendon of the last phalanx; 4, coffin bone; 5, tendon of extensor digiti; 6, tendon of flexor sublimus; 7, tendon of flexor profundus; 8, section of the posterior expansion of the great cartilage; 9, soft cushion of the heel; 10, section of horny hoof; 11, sensitive hoof; 12, anterior section of the cartilage spreading over the coffin bone.

The objects attained by the introduction of this admirable structure into the foot of the soliped are various, and have been well pointed out by Bracy Clark, in his excellent treatise, to which we must refer the reader for many practical applications connected with the veterinary art, that would be foreign to the objects of the present article. First, seeing that the resistance of a solid unyielding support would have been inadmissible, the pedal cartilages are employed as a substitute for bone, and made to occupy a very large share in the composition of the hinder part of the foot; for it will be remarked, the coffin bone, except by its extremity, does not extend beyond the middle of the hoof (*fig.* 515.), the posterior shape of the foot being almost wholly communicated by the cartilage, which, passing nearly around the whole coronary circle, serves to support and convey the skin to its lodgment in the coronary concavity of the hoof. Secondly, it serves to equalise the pressure every where over the internal surface of the hoof when under the pressure of the weight from within, during the descent of the bones of the foot, and, what is singular, the hoof itself is the most solid material of these hind parts of the foot.

A more important office still remains to be explained, namely, that of supplying the coffin bone with a considerable share of its capability of motion in the interior of the hoof; for it is to be remarked that, as the coffin bone is obliged to describe in its descent a small portion or segment of a circle, at its back part, round its centre of motion, or rather its more fixed part (for there is none of it wholly fixed), towards the front of the foot; so this could not so well have been accomplished had the bone itself been fixed at its upper part to the processes in front of the hoof, these being too inconsiderable to afford, in that part of the bone, the extent of motion required; but, by the intervention of an elastic cartilage between the bone and the substance of the hoof, the bone acquires greater liberty for action, and movement of its upper parts.

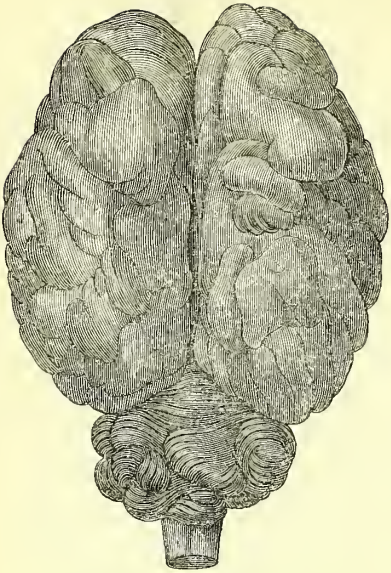
The cartilages of the foot, in old horses, not unfrequently become partially ossified, in which condition they are known to farriers by the name of ring-bones.

Soft Parts of the Foot. — On removing the hoof, and its horny appendages situated beneath the sole of the foot, the whole subjacent surface is found to consist of a thick, villous looking, and highly vascular membrane, moulded exactly to its inner surface, to which the name of *sensitive foot* is generally applied; or, according to the structures beneath which it is situated, it is sometimes divided into sensitive hoof, sensitive frog, &c. This structure is, indeed, the matrix from which the entire corneous hoof derives its origin, and is essentially similar, in its texture and functions, to the soft core upon which the hollow horns of many ruminants and the vascular secreting surfaces upon which the nails and claws of unguiculate quadrupeds are formed. Externally it presents, upon the anterior surface of the foot, the broad vascular laminæ which interdigitate with the horny plates, projecting from the interior of the hoof, as described above, so as to amplify, to a very considerable amount, the extent of surface whereby the contact between the sensitive foot and the wall is effected.

This entire surface is richly supplied with nerves and bloodvessels, the latter of which open into capacious plexuses, that surmount the coronary margin of the hoof (*fig.* 514.), and, when injected, present a very beautiful appearance.

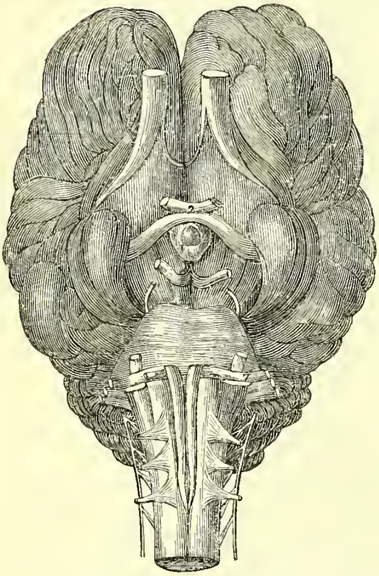
Nervous System and Organs of the Senses. — The general arrangement of the nervous system and structure of the organs of sensation offer in the class before us no peculiarities of sufficient physiological importance to require a detailed description: we append, however, figures representing the cerebral convolutions and the base of the encephalon of the horse for comparison with similar figures given in other articles.

Fig. 516.



Brain of the Horse, showing the Convolutions.

Fig. 517.



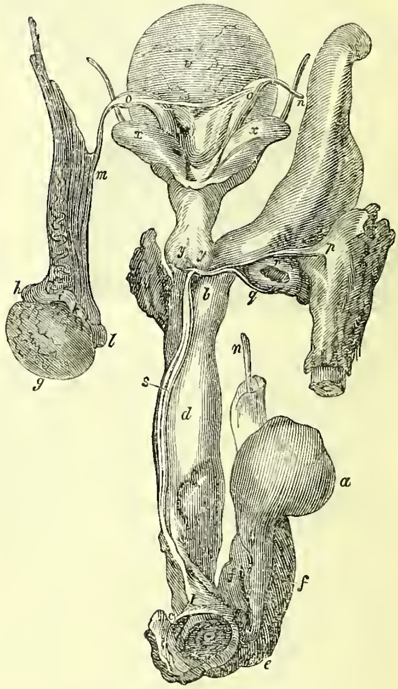
Base of the Brain of the Horse, showing the origin of the Cerebral Nerves.

Organs of Generation. *Male Generative Organs.* — The external organs of generation in the male solipeds are remarkable for their great development, and in nearly equal proportion are these animals conspicuous for their vigorous and fruitful generative powers, which, however, are only called into full activity at a certain season of the year, namely, in this climate, from the beginning of April till the latter end of June, during which period he will efficiently serve fifteen or eighteen mares.

The *scrotum* is suspended between the thighs at a distance of about nine inches beneath the anus, whence it is prolonged forwards, to terminate in the prepuce (*fig.* 518. *a, f, e*).

The *penis* (*fig.* 518. *b, c, d*) is full a foot in length even in its undistended state, measuring from the bifurcation of the corpora cavernosa (*b*) to the extremity of the glans (*e*), which latter organ is itself nearly half a foot in length, and four inches in circumference; its shape is cylindrical, and it is covered with a soft and smooth skin.

Fig. 518.



Organs of generation of the Stallion. (After Daubenton.)

a, the scrotum; *b, c, d*, the penis; *e*, the prepuce; *f, f*, the rudimentary mammæ; *g*, the left testicle removed from the scrotum; *h*, the epididymus; *i, k*, the upper margin of the testis; *l, m*, vas deferens; *n*, vas deferens from the opposite side; *o, o*, enlargements of the vas deferens before their termination; *p, q*, tendinous bands derived from the root of the tail, these, after embracing the end of the rectum, *r*, run along the penis, *s*, as far as the prepuce, *t*, where they terminate; *v*, the urinary bladder; *x, x*, vesiculæ seminales; *y, y*, Cowper's glands.

The *testicles* (one of which only (*g*) is represented in the figure) are of an ovoid flattened form, each being about three inches long by two inches broad, and one inch and a half thick: the *epididymus* (*h*) issues from its anterior part, and is composed of large tubes of a yellowish colour, bound up together in

numerous small bundles. Arrived at the posterior extremity of the testes, the epididymus folds back upon itself, to constitute the vas deferens; which, at its commencement, is very tortuous, and forms a protuberance of considerable size (*l*). The *vasa deferentia* (*l*, *m*, *n*) are upwards of fourteen inches in length, and, during the greater part of their course, about two lines in diameter; but towards their termination they become, for a length of about seven inches, much dilated, here measuring upwards of fifteen lines in circumference (*oo*). The caliber of the internal canal does not, however, expand in proportion to the dilatation of the exterior of the duct.

Female Organs of Generation. — The generative organs in the female solipeds offer no variations of structure from the usual type common to placental quadrupeds. The *clitoris* (*fig.* 519. *a*) is of great size, and is lodged in a cavity appropriated to its reception, situated immediately above the inferior (*i. e.* anterior) commissure of the labia pudendi; its glans is enclosed in an ample prepuce, above which may be observed an orifice leading into a cavity big enough to lodge a small bean. The canal of the *vagina* is about a foot in length, and in its capacity corresponds with the ample dimensions of the penis of the other sex.

Immediately behind the orifice of the urethra, the mucous membrane of the vagina forms a broad fold, which is directed forwards and lies immediately over the urethral opening: the length of this fold in the adult mare is about eight inches, and, near its middle, it is upwards of an inch in breadth.

The *urinary bladder* is small in comparison with the size of the animal; its shape is nearly round; and its circumference, when moderately distended, about a foot and a half. The urethra is remarkably short and capacious, the circumference of its canal being about three inches, while its length is only about an inch and a quarter.

The *orifice of the uterus* (*i*) projects to the distance of about half an inch into the upper end of the vagina, and is of a rounded shape, encircled by a thick margin. The womb is made up of the body and two cornua, which latter, in the unimpregnated state, measure about seven inches in length.

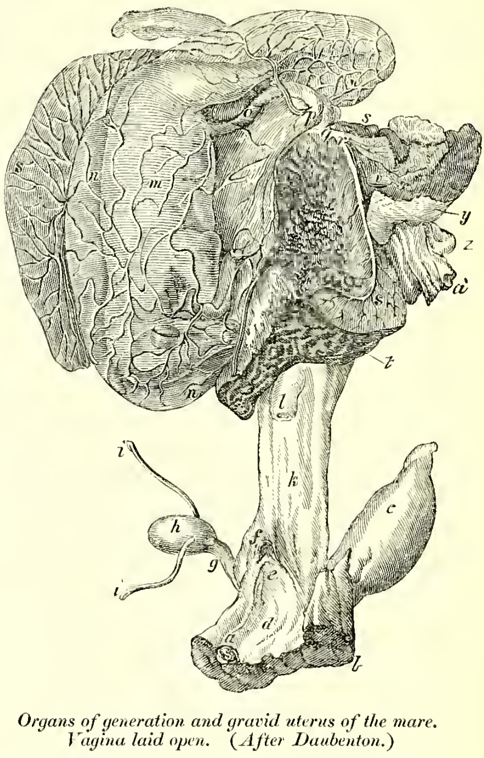
The *ovaria* and *fallopian tubes* present nothing remarkable in their structure or arrangement.

Gravid Uterus. — The anatomy of the contents of the gravid uterus, and the arrangement of the membranes that enclose the fœtus offer some peculiarities worthy of notice.

The fœtus in utero in the solipeds, is enveloped in the usual uterine membranes, — the amnion, the chorion, and the allantoid; but the disposition of these envelopes differs remarkably from what exists in the ruminants, and many other quadrupeds.

The *urachus* (*fig.* 520. *a*) issues from the umbilicus in company with the umbilical arteries and vein (*b*), and, in the ovum represented in the figure, was found at some distance from the umbilical opening to measure about five inches in circumference, beyond which point its diameter gradually diminishes, till it reaches the point at which the amnion spreads out on all sides to envelope the fœtus, where it terminates by the orifice *c*, and is prolonged to form the allantoid, which encompasses the rest of the cord. On the arrival of the allantoid at the extremity of the cord, it extends itself upon the chorion to which it becomes adherent, lining its internal surface in such a manner, that the two seem to form but a single membrane, the inner surface of which is formed by the allantoid (*g*), its exterior by the chorion (*h*).

Fig. 519.



Organs of generation and gravid uterus of the mare. Vagina laid open. (*After Daubenton.*)

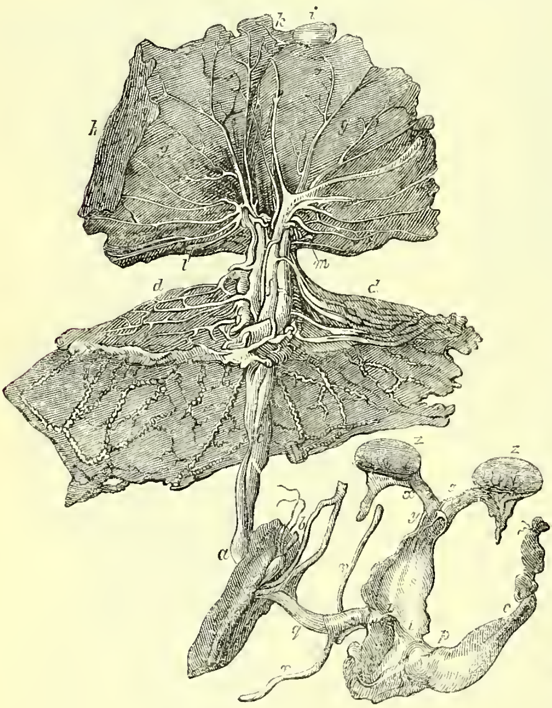
a, the clitoris; *b*, anus; *c*, rectum; *d*, posterior surface of the vagina; *e*, the orifice of the urethra; *f*, membrane which covers the urethral opening; *g*, the canal of the urethra; *h*, the bladder; *i*, *i*, the ureters; *k*, continuation of the vagina; *l*, orifice of the womb; *m*, fœtus as seen through the transparent amnion, *n*; *o*, portion of the umbilical cord that extends from the umbilicus of the fœtus as far as *p*, the point where the amnion spreads out; *q*, portion of the umbilical cord which extends beyond the amnion to the point *r*, where the chorion and the allantoid become united; *s*, the allantoid; *t*, the chorion seen from its outer surface; *v*, a hippomanes attached by its pedicle; *x*, *y*, chorion adherent to the uterine walls by numerous rugæ; *z*, the left ovarium; *a'*, the spermatic vessels.

The size of the umbilical cord gradually enlarges as it approaches the chorion, owing to the progressive dilatation of the vessels

composing it as they recede from the umbilicus.

The *allantoid* in the mare does not form a closed bag, as it does in the ruminants, but lines about half of the interior of the cavity that exists between the amnion and the chorion. To form an idea of this cavity and of the space occupied by the allantoid, it will be necessary first of all to consider the amnion as a sac, in which the fœtus is enclosed, and the allantoid and the chorion as forming another sac of larger size, by which the former is enveloped in such a manner, that an interspace is left between the two: this interspace is traversed by the second portion of the umbilical cord as it passes from the former sac towards the latter, and in this course, the cord is enveloped by the allantoid membrane, which subsequently invests all the interior of the second sac formed externally by the chorion.

Fig. 520.



Anatomy of the gravid uteris of the mare. (*After Daubenton.*)

a, the urachus emerging from the umbilical opening of the fœtus, accompanied by the umbilical vein; *b*, and by two umbilical arteries; *c*, continuation of the umbilical cord as far as the expansion of the amnion; *d*, *d*, *e*, termination of the urachus; *f*, continuation of the umbilical cord; *g*, *g*, allantois; *h*, the chorion; *i*, an hippomanes adherent to the allantoid by its pedicle; *k*, *l*, *m*, two other hippomanes of smaller size. The other letters refer to the generative organs of the fœtus (a female) shown in connection with the above parts; *o*, the rectum; *p*, the anus; *q*, the bladder of urine communicating with the urachus; *r*, *r*, the ureters; *s*, canal of the vagina; *t*, orifice of the urethra; *v*, first appearance of the membrane, which subsequently spreads over the urethral orifice; *x*, *x*, the cornua uteri; *y*, separation between their internal cavities; *z*, *z*, the ovaria.

The aperture of the urachus pours forth a glairy fluid of a reddish colour, which is received into the cavity, the boundaries of which are described above: this fluid has a urinous smell, especially when heated, and moreover contains certain solid bodies, which have been from time immemorial dignified with the name of *hippomanes*, and were by the ancients supposed to be possessed of various mysterious qualities, and magical influences.

The *Hippomanes* was considered, until a very recent period, to be a piece of flesh growing upon the forehead of the nascent foal; and it was not until Daubenton presented a memoir upon this subject to the Royal Academy of Sciences in Paris *, that its real nature was understood. The hippomanes were then found to be merely masses, of a thick substance, of variable dimensions, contained in the allantoid cavity, which, although they might occasionally during parturition after the laceration of the membranes, become adherent to the head of the fœtus, are, in reality, produced between the amnion and the allantoid membranes.

These bodies are very variable in their size, and frequently several are met with, the dimensions of which vary from the size of a pea to that of a large pear, some of the latter weighing as much as five or six ounces. They are composed of a viscid substance of an olive brown colour, and frequently have irregularly shaped cavities in their interior; but they present no traces of organization. When cut into they seem to be made up of numerous superposed layers, and externally their surface is covered with floating filaments: sometimes they are found to be attached by long pedicles to the walls of the allantoic cavity; but, whatever their shape, they are evidently merely sedimentary deposits from the fluid in which they are immersed, and indeed may be formed at pleasure by slowly evaporating the contents of the allantoic sac. These structures are indeed by no means peculiar to the horse, but are frequently met with in other animals.

The exterior of the chorion is everywhere in contact with the uterine walls, and in shape represents exactly the interior of the cornua uteri, upon which it is moulded, the placenta occupying the greater portion of its extent.

Mammary Glands.— It was generally believed from the time of Aristotle until a very recent period, that in the male horse there were no nipples or other rudiments of the

* Mémoires de l'Académie Royale des Sciences, années 1751 and 1752.

female mammæ; except, as Aristotle expresses it, in such animals as resemble their mothers*: that is to say, in other words, that there were a few exceptional cases. Subsequent authors have stated the same concerning male solipeds in general†, although none stated in what the resemblance consisted, or where the mammæ in those furnished with them were situated; so that even Buffon asserted it as a fact, that the male solipeds had no vestiges of mammæ. Daubenton, however, having previously discovered the situation of these organs in the male ass, was led from analogy to expect their presence in the horse likewise, and soon detected them, but situated in a very unusual position, — namely, upon the prepuce of the animal. The prepuce of the stallion is found to form a kind of prominent ring around the aperture through which the penis is protruded, and it is upon this circular protuberance, close to the sides of the scrotum, that the mammæ are situated. These organs are two in number (*fig.* 518. *ff*), situated at a distance of about half an inch from each other, and are easily distinguishable from the circumstance of the skin being raised into a papilla around each nipple, in the centre of which there is a shallow depression. It would seem, however, that in old horses the presence of these rudimentary mammæ becomes less apparent.

In the mare, the mammary glands are situated between the thighs at a distance of about nine inches in front of the vulva. The nipples are only two in number, one on each side of the mesial line, and their distance from each other is not more than an inch and a half. As in the goat and many herbivorous quadrupeds, all the lactiferous ducts form, in the base of each gland just above the root of the nipple, a large hollow cavity, which is divided by an internal septum into two chambers, one situated in front, and the other behind; from each chamber a separate duct is derived, which passes along the nipple as far as its extremity, where it terminates. The orifices of these canals are situated, one behind, the other about a line, apart. It is owing to the presence of the reservoirs thus formed by the cavities of the mammary glands, that the lacteal secretion is permitted to accumulate in considerable quantities, until required for the nourishment of the young, or removed by human agency for the purpose of procuring the milk, which is frequently employed as an article of diet.

Bibliography.— *Buffon* et *Daubenton*, Histoire Naturelle, tom. iv. 4to. Paris, 1753. *Cuvier*, Anatomie Comparée. *Clark, Bracy*, A Series of original Experiments on the Foot of the living Horse, 4to. 1809. *Clark, Bracy*, Sectional Figure of the Horse, with Remarks on certain Properties of his general Framing, 4to. London, 1813. *Stubbs, George*, The Anatomy of the Horse, London, fol. 1766. *Bourgelat*, Elémens de l'Art Vétérinaire. *Lafosse*, Cours d'Hippiatrique. *Vitet*, Médecine Vétérinaire, Lyons, 1783.

(*T. Rymer Jones.*)

* *Equi mammas non habent, nisi qui matri similes prodiere.* — Arist. de Partib. Anim. lib. iv. cap. 9.

† *Solidungula mascula mammas non habent præterea quæ matribus similia sunt.* — Rai, Synops. method. Anim. quad. &c. p. 64.

SPINAL ACCESSORY NERVE (part of the sixth pair of the older anatomists; part of the eighth pair of Willis; *nervus accessorius ad par vagum; nervus accessorius Willisii*; the eleventh pair of Soemmering; the *beinerve* of the German anatomists). This nerve is attached to, or, as it is more commonly expressed, arises from, the lateral surface of the cervical portion of the spinal chord close to the posterior roots of the spinal nerves; and it lies between the posterior roots of the spinal nerves and the ligamentum denticulatum. On entering the cranium by the foramen magnum, it continues to receive additional roots or filaments of origin from the medulla oblongata. It commences by a very slender filament, most generally opposite the fifth or sixth posterior roots of the spinal nerves, and in its passage upwards to the interior of the cranium, its bulk is gradually increased by additional filaments of origin from the lateral surface of the spinal chord and from the medulla oblongata. The filaments arising from the spinal chord pass upwards and a little forward to join the trunk of the nerve, so that it lies a little nearer to the ligamentum denticulatum than the attachments of the filaments forming it. After it enters the cranium by the foramen magnum, it runs forward, outward, and upward, places itself in close apposition to the posterior surface of the par vagum, and escapes from the interior of the cranium, through the foramen lacerum posterius, along with the vagus and glosso-pharyngeal nerves. The roots of the accessory that arise from the medulla oblongata are placed in the same line with the lower roots or filaments of origin of the par vagum; and the upper roots of the former approach so closely to the lower roots of the latter, that it is frequently difficult to say with confidence where the roots of the one nerve end and those of the other begin. (*Fig.* 521, 3, 5.)

Previous to the time of Willis, anatomists considered this nerve as constituting a part of the vagus, and to him is due the credit of first pointing out clearly the grounds on which its separation from the vagus rests. Very great discrepancy exists in the description of the origin of this nerve given by the best anatomists. This is explained, not only by the fact first pointed out particularly by Scarpa*, that its filaments of origin are attached over different extents of the spinal chord in different individuals, and sometimes to a greater extent on one side than on the other in the same individual, but also by its lower roots or filaments of origin being so slender that they sometimes cannot be accurately traced by the naked eye. Willis himself describes it as commencing by a very slender beginning near the sixth or seventh cervical nerve.† Scarpa ascertained that its

* Abhandlung über den zum achten Paare der Gehirnerven hinlaufenden Beinerven. In den Abhandlung der röm. K. K. Josephinischen Med. Chir. Academie, Band i. Wien, 1787.

† Cerebri Anatome, &c., Caput xxviii. p. 294. Amstelodami, 1666.

lowest root may be attached to the spinal chord opposite the fourth, fifth, sixth, or seventh cervical nerve, but more frequently between the fifth and sixth; and that when its roots are extended over a more limited portion of the spinal chord, this is compensated for by their being proportionally stronger.*

Anatomists have differed as widely in their account of the particular column or tract of the spinal chord to which the roots of the spinal accessory are attached, as they have done regarding the extent of the spinal chord over which these roots stretch. This is a point in the anatomy of the nerve which has assumed greater importance since the discovery by Sir Charles Bell, of the separate functions of the anterior and posterior roots of the spinal nerves, and is of much more interest to the modern, than it was to the older anatomists. The filaments of origin or roots of this nerve that come from the spinal chord are attached to the chord near the posterior lateral groove separating its posterior and middle columns, and close upon the posterior roots of the spinal nerves, so that we can readily understand how some anatomists should describe these roots as arising from the middle column, and others describe them as springing from the posterior column.† Among the modern anatomists we find Bellingeri, who has attended particularly to the anatomy of this nerve, describing it as arising from the middle or lateral column of the spinal chord*, while Bischoff† and Bernard‡ trace its origin to the posterior column; and Bendz§ states that while nearly the whole of its roots come from the middle column, a few arise between the posterior roots of the spinal nerves and from the posterior column.‖ From my own examinations of the attachments of this nerve, I had arrived at the conclusion that it arises from the posterior part of the middle column, and that its middle and inferior roots are attached along the course of the decussating fibres of the pyramidal column, which form the posterior part of the middle column of the chord.¶ Stilling says** that the lower and middle roots of this nerve can be traced to the anterior grey substances in the chord, from which the anterior roots of the spinal nerves arise, and that, in an anatomical point of view, they must be regarded as performing the same functions as the anterior roots of the spinal nerves; while the upper roots, or those which are attached to the medulla oblongata, differ in a marked manner, in regard to their origin, from the lower and middle roots. He states that these upper roots above the first cervical nerve arise from a grey mass in the medulla oblongata, which he styles the *accessory-kernel* (accessorius-kern††), and that they resemble closely the lower filaments of origin of the par vagum. These upper roots of the accessory do not arise from the gelatinous substance from which, according to Stilling, the posterior roots of the spinal nerves spring, yet they come into closer relation with it the nearer they approach to the commencement of the roots of the vagus. The upper fibres of the accessory, though not continuous with the posterior roots of the spinal nerves, are yet, he believes, analogous to these; and this view is strengthened by their presenting the same connection with the roots of the hypoglossal as is found between the roots of

* Huber (De Medulla Spinali, et speciatim de Nervis ab eâ provenientibus, p. 13.) says that this nerve commences opposite the seventh cervical, but he afterwards speaks of it arising opposite the sixth. Lobstein (De Nervo Spinali ad Par Vagum Accessorio, p. 233, as reprinted in Ludwig's Script. Neurol. Min. Selec. tom. ii. Lipsiæ, 1792) describes it as arising under the sixth pair of cervical nerves by a slender beginning. Bellingeri (De Medulla Spinali, Nervisque ex eâ prodeuntibus, p. 74, 1823) places its origin opposite the seventh cervical nerve. Cruveilhier (Anatomie Déscriptive, tom. iv. p. 899, 1835) says that its origin seldom passes below the level of the fifth pair of cervical nerves, but it may arise opposite the sixth and even the seventh pair. Bendz (De Connexu inter Nervum Vagum et Accessorium Willisii, p. 22, 1836) describes its lowest root as arising from the spinal chord in the region of the fifth or sixth cervical nerves, and rarely as low as the posterior root of the seventh cervical. Valentin (Soemmering vom Baue des menschlichen Körpers, Hirn und Nervenlehre, S. 513, 1841) states that its most frequent origin is opposite the sixth, or between the sixth and seventh cervical nerves; sometimes it arises opposite the fourth or fifth, or it may extend as far as the seventh, and in rare cases as far as the first dorsal. Krause (Handbuch der menchlichen Anatomie, Erster Band, S. 1066; Hannover, 1842) says that it usually arises opposite the upper part of the roots of the seventh cervical, seldom higher. Bernard (Archives Générales de Médecine, 4ième série, tom. iv. p. 410, 1844) describes it as arising by a series of bifid or trifid nervous filaments, which extend, in man, from the origin of the pneumogastric to a point opposite the fourth or fifth pair of cervical nerves.

† Rolando (Recherches Anatomiques sur la Moëlle Ablongée) and Serres (Anatomie Comparée du Cerveau, tom. i.) have stated that the lower fibres of this nerve come from the anterior column of the spinal chord.

* De Medulla Spinali, Nervisque ex eâ prodeuntibus, pp. 51. 55, 1823.

† Nervi Accessorii Willisii Anatomia et Physiologia, p. 11. Darmstadii, 1832.

‡ Archives Générales de Médecine, 4ième serie, tom. iv. pp. 409, 410, 1844.

§ Tractatus de Connexu inter Nervum Vagum et Accessorium Willisii, pp. 22. 39. Hauniae, 1836.

‖ Lobstein (De Nervo Spinali, in Ludwig's Scriptores Nevrologici Minores Selecti, tom. ii. p. 233.) also describes some of the filaments of origin of the spinal accessory as coming from the spinal chord between the fasciculi which constitute the posterior roots of the spinal nerves, and has represented these in *fig.* 1. Those who may wish to ascertain the opinions of other anatomists as to the particular column of the spinal chord into which this nerve is implanted, and the extent of its attachment to the cervical portion of the spinal chord, may consult the monographs of Bischoff and Bendz quoted above, and especially that of the former of these authors.

¶ On some points in the anatomy of the medulla oblongata, in Edinburgh Medical and Surgical Journal for 1841.

** Ueber die Textur und Function der Medulla Oblongata, pp. 55. 57. Erlangen, 1843.

†† He describes the position and structure of this accessorius-kern at p. 23. of the work quoted.

the posterior and anterior spinal nerves at their origin.

The spinal accessory in its course within the spinal canal frequently forms communications with the posterior root of the first cervical, and much more seldom with the posterior root of the second cervical nerve.* When these communicating filaments come from the second cervical, they are generally few in number. This communication between the spinal accessory and the posterior root of the first cervical is, according to Lobstein, more frequently present than absent.† When the posterior root of the first cervical joins itself, either in whole or in part, to the spinal accessory, a branch of equal size generally leaves the accessory, either at the point where it is joined by the posterior root of the first cervical, as figured and described by Asch ‡, or a little above this junction, as figured by Huber §, and described by Bellingeri.|| This branch, after leaving the accessory, proceeds outwards, approaches the anterior root of the first cervical, and takes the place of the posterior root of that nerve.¶ When the posterior root comes from the accessory, it generally presents a ganglion in the usual position. Sometimes, however, though rarely, this ganglion is found on the accessory where the posterior root of the first cervical leaves it to join itself to the anterior root. This ganglion was first pointed out by Huber; its existence has been denied by Lobstein, Asch, Haller, and Scarpa, and it has again been described by Bellingeri. I have seen this ganglion twice, and it was present on one side only. It becomes an interesting question in a physiological point of view to know, whether or not the whole of the filaments of the posterior roots of the spinal nerves which join themselves to the accessory, again leave it to form the posterior root of the first cervical. Bellingeri answers this question in the affirmative. "The filaments," he says, "coming from the posterior roots to the accessory are not intermixed, but only approximated, so that they can be separated by slight traction."**

* Scarpa states (opus cit. p. 395.) that in a great number of bodies he examined with a special reference to this point, he found a communication between the accessory and the posterior root of the second cervical only in two instances.

† Circa harum radicularum, quæ pro radicibus posticis primi paris habenter, communicationem illud notamus, quod sæpius accessorium subire, quam eundem intactum relinquere observenter. Opus cit. p. 223.

‡ De Primo Pare Nervorum Medullæ Spinalis, tab. x. fig. 2.; et explicatio, p. 335. Ludwig Scrip. Nevr. Min. Sel. tom. i.

§ Opus cit.

|| Opus cit. p. 80. Monro *secundus* has also given a representation of this communication between the accessory and posterior root of the first cervical. Observations on the Structure and Functions of the Nervous System, tab. x. fig. 2. 1783.

¶ Bischoff states (opus cit. pp. 34. 82.) that in none of the numerous instances in which he dissected the accessory in the lower animals, did he ever observe any filaments of the posterior roots of the spinal nerves join themselves to it.

** Opus cit. p. 81.

And in another place he says, "I believe that the filaments from the posterior roots, which join the accessory, leave it again to proceed to the posterior root of the first cervical."* From this he concludes that the accessory contains no sensiferous filaments. Müller, on the other hand, has adduced some unusual anatomical arrangements in this nerve, which may be regarded as favouring the opinion that it contains sensiferous filaments independant of those which it may receive from the posterior roots of the spinal nerves. He mentions an instance†, which he elsewhere ‡ describes at considerable length, where the posterior root of the first cervical nerve on the right side was not present, and where its place was supplied by two bundles of filaments from the superior part of the spinal accessory. The upper of these bundles, at least, came from the medulla oblongata. Upon the posterior root of the first cervical thus constituted, a ganglion was formed while it was still within the *theca vertebralis*. The upper fibres of the posterior root of the second cervical of this side joined themselves to the accessory, but no nervous filaments were attached to the spinal chord in the usual position of the posterior root of the first cervical. On the left side, the posterior root of the first cervical presented its usual appearance, and was connected to the spinal accessory by some filaments of communication. The filaments of the accessory arising from the medulla oblongata did not, as on the right side, divide themselves into two parts, one of these becoming the substitute of the posterior root of the first cervical: but the whole ran upwards into the accessory nerve.|| Müller also states that Hyrtl has often seen a ganglion upon the accessory nerve opposite the entrance of the vertebral artery into the interior of the cranium; and that Remak showed him an instance of a ganglion upon the spinal accessory at its passage through the foramen lacerum. "I do not, however, affirm," Müller remarks in reasoning from these cases, "that the spinal accessory always contains originally sensiferous filaments, but leave it doubtful." "But in the case," he continues, "where the nervus accessorius forms an intimate connection with the posterior root of the first cervical, or any other nerve, we may suppose an interchange; and this, in the same degree, will render probable the idea of Monro,

* Ibid, p. 79.

† Archiv. für Anat. und Physiol. 1834, p. 12.

‡ Idem opus, 1837, pp. 279—281.

§ Arnold (Bemerkungen über den Bau des Hirns und Rückenmarks, &c., S. 181—183; Zürich, 1838) has published remarks upon this anomalous instance in the origin of the posterior root of the first cervical from the accessory, the object of which is to endeavour to show that Müller had misinterpreted the facts observed. Among other things urged with this view, is the circumstance that the posterior root of the first cervical does not arise usually in the same line with the posterior roots of the other spinal nerves, but somewhat anterior to these. We cannot, however, believe that so experienced and accurate an anatomist as Müller is, could fall into any such mistake as is here insinuated.

that the communication of the spinal accessory with the posterior root of the first, or with any other spinal nerve, will be an equivalent to it for a posterior root." We have already seen that Stilling concludes, on anatomical grounds, that those filaments of the accessory that come from the medulla oblongata contain centripetal filaments.*

The spinal accessory passes through the foramen lacerum posterius in a canal formed by the dura mater, common to it and the vagus, but they are occasionally separated from each other as they enter this canal by a bridle of arachnoid, or of the dura mater. Soemmering has pointed out that the accessory does not perforate the dura mater like the other nerves, but is, as it were, insensibly surrounded by this membrane.†

One or two filaments generally pass between the accessory and the superior ganglion or *ganglion jugulare* of the vagus, as they lie in the foramen lacerum posterius. Hein states that he has more than once distinctly observed, as also Krause has remarked, the superior five, or even six filaments of the root of the accessory approximate very closely to the ganglion jugulare of the vagus, and partly enter into its formation, so that a junction between the vagus and accessory had already taken place in this ganglion, before the filaments of the accessory had been fully collected to form together the trunk of this nerve.‡

As the spinal accessory is passing through the foramen lacerum, it is in close proximity to the posterior surface of the par vagum, and it there divides into its two branches — its *internal* and *external* branches.

The former, or the *internal*, is composed of the filaments forming the upper roots of the nerve (*fig.* 521, 11.), and entirely, or almost entirely, of those coming from the medulla oblongata; and it joins itself to the vagus immediately below the ganglion jugulare of that nerve. The passage of the accessory through the foramen lacerum posterius, its division into two branches, and the distribution of the internal branch as far as it is known, have been already described in the art. PAR VAGUM, vol. iii. pp. 883. and 890, and need not be repeated here.

The *external* branch, composed of those fibres which arise from the spinal chord (*fig.* 521, 12.), proceeds downwards, outwards, and backwards behind the internal jugular vein, in front of the occipital artery, and behind the posterior belly of the digastric and stylo-hyoid muscle, and reaches the inner surface of the sterno-cleido-mastoid muscle at the lower part of its upper third. In continuing its course downwards and outwards, it here generally perforates the sterno-cleido-mastoid; at other times it is only closely connected to it by cellular tissue; but in both cases it gives branches to this muscle. In this part of its course it is strengthened and anastomoses with twigs of the third and second cervical nerves. Continuing its progress downwards and backwards it anastomoses with twigs of the fourth and fifth cervical nerves, and throws itself into the inner surface of the trapezius muscle, among whose fibres it is ultimately lost.

Comparative anatomy of the spinal accessory. — The origin and distribution of this nerve in the mammalia does not essentially differ from what is found in the human species.* Willis states that this nerve is not only present in the mammalia, but also in birds and fishes †; but the existence of it in the two latter divisions of the vertebrata has been subsequently denied by many excellent anatomists. "If an animal," says Mr. Shaw, "does not perform part of the act of respiration by muscles which run from the skull to the chest, no spinal accessory is found. The truth of this observation may be shown by the dissection of any of the larger birds, but the most extraordinary proof is to be found in the neck of the camel. The constitution of the neck of this animal is like that of birds; there being a succession of short muscles along the side of the neck, and attached to the vertebræ, but no long muscle passing from the jaw to the sternum to assist in breathing, as in other quadrupeds." ‡ It appears, however, that in the camel this nerve is present, but it is smaller and differently distributed from what it is in the horse.§ Serres found it in three of the larger birds, Weber in some fishes, and Bischoff has given descriptions and representations of it in several birds, reptiles, and fishes. In these animals the upper part only of this nerve seems to be present, for it does not stretch downwards along the spinal chord to the same extent in them as in the mammalia. The whole of this nerve, in these animals, throws itself into the vagus, while a branch leaves the vagus after it has escaped from the cranium, and taking the place of the external branch of the accessory is distributed to the muscles of the neck in birds and in reptiles, and to the muscles which move the pectoral fin in fishes.‖ In the chimpanzee, the spinal accessory, after passing through the foramen lacerum, divides into two branches. The internal runs towards the larynx, into which it penetrates above the os-hyoid. It is placed between the superior laryngeal nerve and stylo-hyoid ligament, and passes behind the internal carotid artery to the superior hyoi-

* Stilling further states (p. 59) that in an anatomical point of view we may regard the upper roots of the accessory forming the *internal branch* of that nerve as being composed of centripetal and centrifugal filaments, exactly like the vagus.

† "Non reliquorum nervorum more, sub arcu duræ membranæ fertur, sed insensili quasi modo a dura membrana obducitur." De Basi Encephali, &c., p. 104, reprinted in Ludwig's Scrip. Nevr. Min. Sel., tom. ii.

‡ Müller's Archiv. 1844, p. 337.

* Dissections of this nerve upon several mammalia are given in detail by Bischoff and Bendz.

† Opus cit. p. 295.

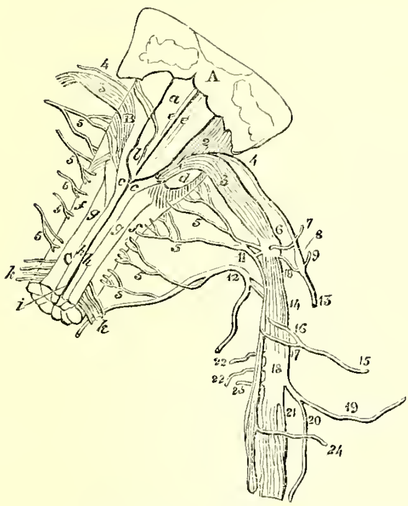
‡ London Medical and Physical Journal, vol. xlix. p. 458, 1823.

§ Vide note by Defermon, at p. 527 of tom. ii. of the Archives Générales de Médecine, 1823.

‖ A full account of the comparative anatomy of this nerve is given by Bischoff.

dean region (la région hyoidienne supérieure), where it terminates. The external branch passes downwards below the sterno-cleido-mastoid muscle to reach the trapezius, in which it is chiefly distributed.*

Fig. 521.



From Bendz, reduced one-half.

A, part of cerebellum cut across; B, medulla oblongata; C, spinal chord; *a*, floor of fourth ventricule; *b*, calamus scriptorius; *c c*, posterior pyramidal bodies; *d*, right restiforme body obliquely divided; *f f*, lateral columns of spinal chord; *h h*, posterior columns of spinal chord; *i*, posterior longitudinal fissure; *k k*, posterior roots of spinal nerves; 3 3, roots of vagus nerve; 4 4, roots of glosso-pharyngeal; 5 5 5, roots of uervus accessorius; 6, ganglion of the root of the vagus or superior ganglion; 7, auricular branch of vagus; 8, right ganglion petrosum of glosso-pharyngeal; 9, ramus anastomicus of Jacobson; 10, communicating branch between the superior ganglion of the vagus and the ganglion petrosum; 11, roots of the accessory which form its internal branch; 12, roots of the accessory which form its external branch; 13, glosso-pharyngeal nerve; 14, trunk of the vagus; 15, pharyngeal branch of vagus; 16, filaments of this branch that come from the vagus; 17, filaments of this branch that come from the internal branch of the accessory; 18, ganglion of the trunk of the vagus or inferior ganglion; 19, nervus laryngeus superior; 22 22, communicating branches between the ganglion of the trunk of the vagus and the superior ganglion of the sympathetic; 23, fibres of the internal branch of the accessory which do not enter into the formation of the ganglion of the trunk of the vagus; 24, branch from these fibres which joins itself to the external branch of the superior laryngeal nerve.

Physiology of the accessory.— The peculiar origin and course of this nerve, and particularly its intimate connection with the par vagum, have formed the basis of most of the speculations on its functions since the time of Willis. It was maintained by Willis that this nerve, from its connection with the par vagum, regulates those involuntary movements of the neck and arm caused by the emotions and passions.* Lobstein likewise believed that the spinal accessory joins the vagus for the purpose of connecting itself with the involuntary functions, and he supposed that its paralysis might also affect the movements of the pharynx and larynx.† Others have maintained that it is a nerve of involuntary motion from the particular portion of the spinal chord in which it is implanted. It is, as is well known, one of Sir Charles Bell's respiratory nerves, arising as he supposed from a particular tract in the spinal chord to which he gave the name of respiratory tract, and is therefore, according to this view, a nerve of involuntary motion. Bellingeri believes that the lateral tract of the spinal chord, from which the accessory arises, presides over the instinctive and sympathetic movements, and that it is consequently a nerve of involuntary motion.‡ Arnold §, Scarpa ||, Bischoff ¶, Valentin **, and Longet ††, have maintained that the accessory stands in the same relation to the vagus as the anterior roots of the spinal nerves do to the posterior roots.‡‡ According to this last view, the vagus does not originally possess any motor filaments, but derives them from the spinal accessory. The two first of these authors came to this conclusion on anatomical grounds alone; the three latter, from experiments upon these nerves in living animals, as well as from their anatomy. Bernard has arrived at the conclusion that it is entirely a motor nerve, and that it enables the larynx and pharynx, and muscles of the neck in which it is distributed, to partake in the production of the phenomena of phonation, but that it does not assist in any of the true respiratory movements.§§ Dr. Todd and Mr. Bowman ||||, on the other hand, believe that the internal branch of the accessory is composed of *afferent* nerves, and that the mode of implantation of this nerve in the central organs of the nervous system serves to bring the sentient surface of the lungs and air-passages into immediate relations with the roots of all those nerves which animate the great muscles of respiration, the phrenic, the external thoracic, the cervical plexus, and the motor fibres of the spinal accessory and vagus nerves.

All experimenters agree that the external

* Recherches d'Anatomie Comparée sur le Chimpansé: par W. Vrolik, p. 40. Amsterdam, 1841.

* Opus cit. caput xxviii.

† Ibid. pp. 345, 346.

‡ Ibid. pp. 89, 90.

§ Der Kopftheil des vegativen Nervensystems. Heidelberg, 1831.

|| De Gangliis Nerv. deque Essentia Nervi Intercost. Ann. Univers. di Medicina, 1831.

¶ Nervi Accessorii Willisii Anatomia et Physiologia, 1832.

** De Functionibus Nervorum Cerebralium et Nervi Sympathici, 1839.

†† Anatomie et Physiologie du Système Nerveux, &c., tom. ii., 1842.

‡‡ It appears that this idea had been previously suggested by Görres (Exposition der Physiologie, Coblentz, 1805, as quoted by Müller).

§§ Archives Générales de Médecine, 4ième serie, tom. iv. and tom. v., 1844.

|||| The Physiological Anatomy and Physiology of Man, vol. ii. p. 130.

branch of the spinal accessory is a motor nerve. We found that when it was embraced firmly within the forceps, or tied tightly soon after it had emerged from the foramen lacerum, the animal gave indications of suffering * ; but an experiment of this kind does not enable us to decide whether these sensiferous filaments were originally contained in the accessory, or were derived from the neighbouring nerves. Mr. Shaw has detailed an experiment to show that the movements which it imparts to the sterno-mastoid, and to the trapezius are not voluntary, but respiratory.† In our experiments, and in those subsequently performed by Bernard, these muscles acted in unison with the muscles of respiration after the spinal accessory nerves had been divided.

While all experimenters agree that the external branch of the accessory is chiefly if not entirely composed of motor filaments, they have arrived at discrepant conclusions regarding the functions of the internal branch. Volkmann ‡, Van Kempen §, and Stilling ||, observed no movements of the muscles in which the internal branch of the accessory is distributed, on irritating the roots of this nerve within the cranium; while in those of Bischoff, my own, those of Valentin ¶, Longet **, Hein ††, Morganti ‡‡, and Bernard §§, partly consisting of irritating the roots of the nerve within the cranium after death, and partly, as in those of Bischoff, Longet, Morganti, and Bernard, by lesions of the nerve in living animals, and observing their effects upon the movements of the muscles in which it is distributed, proofs of its being a motor nerve were believed to be obtained. We think that this evidence is sufficiently strong to justify the belief that the internal branch of the accessory does contain *motor* filaments; but it is at the same time highly probable that it is partly composed of *sensiferous* and *afferent* filaments, and if so, its constitution must be similar to the vagus nerve, with which it becomes so closely incorporated. In the art. Par Vagum, sufficient proof has been adduced to satisfy us that the opinion that the spinal accessory furnishes all the motor filaments contained in the trunk of the vagus, is no longer tenable.

(*John Reid.*)

* Edinburgh Medical and Surgical Journal for January, 1838. Valentin states (opus cit. pp. 58. 62.) that he succeeded in increasing the action of the heart by irritating the trunk of the accessory; but Van Kempen (opus cit. p. 65) repeated this experiment without success.

† London Medical and Physical Journal, vol. xlix.

‡ Müller's Archiv. 1840.

§ Essai Experimental sur la Nature Fonctionelle du Nerf Pneumogastrique : Louvain, 1842. In giving the results of Van Kempen's experiments in the art. Par Vagum, foot-note at p. 891, vol. iii. upon the effects of irritating the roots of the vagus within the cranium, I have inadvertently written the palato-glossus muscle *instead of* the palato-pharyngeus or pharyngo-staphylin muscle, as one of the muscles seen to contract in this experiment. I may also here correct another error in the same article: at p. 900, it is stated that Longet believes that the secretion of the gastric juice is greater after section of the vagi than in the sound animal; while in fact he states that it is diminished by section of the vagi, and that this diminution in the secretion may be explained on mechanical grounds.

|| Bischoff's Bericht über die Fortschritte der Physiologie im Jahre 1842, S. 154. In Müller's Archiv. 1843.

¶ Opus supra cit.

** Opus supra cit.

†† Müller's Archiv. 1844.

‡‡ Omodei, Annali Universali di Medicina. Juli, 1843.

§§ Opus supra cit.

SPINAL NERVES (*Les Nerfs rachidiens*, Fr.; *Die Rueckenmarksnerven*, Germ.; *I Nervi Spinali*, Ital.) are thirty-one pairs, and are distributed to the neck, and the upper extremities, the trunk and lower extremities. They are divided into Cervical, Dorsal, Lumbar and Sacral : the first division comprising eight; the second, twelve ; the third, five ; and the fourth, six. Their general and special characters, and their apparent and absolute connexion with the spinal chord having been already described *, we shall limit the details of this article to their ultimate distribution.

Each spinal nerve, after the union of its roots, divides into an anterior and posterior branch, the former having generally a much more complicated and extensive distribution than the latter. It will be convenient therefore for the purpose of description to enter first into a consideration of the posterior branches.

The posterior branch of the first cervical or sub-occipital nerve is larger than the anterior, and passes internal to and below the vertebral artery, between the arch of the atlas and the occipital bone, to gain the triangular space between the rectus capitis posticus major, the superior and inferior oblique muscles. It is here imbedded in a considerable quantity of fat and dense cellular membrane, and having directed itself from before, backwards, and slightly from below upwards, divides into a series of branches. Two external branches are sent to the two oblique muscles: an internal ascends to the rectus capitis posticus major, and which having supplied this, terminates in the minor : another filament is directed to the anterior aspect of the complexus near to its occipital attachment: and the terminal branch descends, generally perforating the inferior obliquely, and anastomoses with the posterior branch of the second cervical nerve.

The posterior branch of the second cervical nerve emerges from between the lower border of the posterior arch of the atlas, and the lamina of the axis, and is larger than any of the posterior branches of the cervical nerves, and three or four times greater than the anterior branch of the same nerve. It appears at the lower border of the inferior oblique, and having passed a short distance horizontally inwards, winds round this muscle to the anterior aspect of the outer part of the complexus, which it perforates. It inclines outward and upwards between it and the

* Vide Nervous System, vol. iii. p. 657.

trapezius, passes through the latter, and terminates in the skin in the occipital region as the *great occipital nerve*, coursing along with the occipital artery but lying internal to it. Before becoming great occipital, it gives off at the lower border of the inferior oblique a branch to supply this muscle and a superior and inferior anastomotic branch to communicate with the first and third cervical. When passing along the anterior surface of the complexus, numerous branches are given off to this muscle, the trapezius, and splenius. Those for the last muscle are more numerous and larger than the branches, for the two others are directed to the anterior aspect of the muscle, and one or more of them perforate the complexus before reaching it.

The posterior branch of the third cervical is smaller than the second, but larger than the fourth, and situated more externally, emerging from between the transverse processes of the second and third cervical vertebra. It is directed inwards, between the opposed surfaces of the complexus and semispinalis colli towards the median line, and having reached the sides of the spinous processes of the vertebræ, divides into ascending and horizontal cutaneous branches. The *ascending branch*, after a short course, perforates the inner border of the complexus and trapezius, and becomes cutaneous. It continues its course close to the median line, as far as the region of the occiput, the inner and lower part of which it supplies on the internal side of the great occipital nerve.

The *horizontal branch* passes between the ligamentum nuchæ and the inner border of the complexus, and after having perforated the tendon of the trapezius, terminates in external small cutaneous filaments. The nerve prior to division, and at the outer border of the semispinalis colli, communicates by one or more filaments with the posterior branch of the second cervical. From the anastomosis between the communicating branches of the posterior roots of the three first cervical nerves, results an irregular plexus placed between the complexus and outer part of the semispinalis colli, and consequently nearly in a line with the transverse processes of the superior cervical vertebræ. From this *posterior cervical plexus*, numerous branches arise to supply the complexus, splenius, and semispinalis colli. The anastomosis between these posterior branches is, according to Cruveilhier, sometimes deficient.

The posterior root of the fourth cervical nerve varies much as to individual size, but is always smaller than the preceding. It passes downwards and inwards between the complexus and semispinalis colli, and having reached the side of the median line, perforates the tendons of the splenius and trapezius, and becomes cutaneous. In its course it supplies these muscles, and occasionally terminates in the splenius without going to the skin.

The posterior branches of the fifth, sixth, seventh, and eighth cervical nerves have a similar course to the fourth, but decrease in size from above downwards. The fifth and sixth usually pass between the opposed surfaces of the semispinalis colli and complexus, give branches to these muscles, and perforate the inner part of the tendons of the splenius and trapezius, to terminate in the skin at the lower part of the nape of the neck.

The posterior branches of the seventh and eighth cervical nerves pass either through the deep-seated fibres of the semispinalis colli, or between it and the multifidus spinæ, give branches to these two muscles, perforate the tendons of the trapezius and splenius, and terminate by ramifying, the one on the skin above the scapula, the other over the integument, as far as about the spinous process of the third dorsal vertebra. The inter-transversales muscles, cervicalis ascendens, trachelo-mastoid, and transversalis colli, receive numerous small filaments from these nerves almost immediately after their appearance in the neck.

The posterior branches of the dorsal (thoracic) nerves are much smaller than the anterior, and are directed backwards between the ascending costo-transverse ligaments and the sides of the vertebræ. Having reached the outer border of the semispinalis dorsi and multifidus spinæ, they divide into external and internal branches, the latter being muscular and cutaneous in their distribution, the former only muscular in the eight upper. In the first eight the internal branches are larger, in the last four much smaller than the external.

The external or muscular branches of the eight superior pass between the sacro-lumbalis and longissimus dorsi, and give off numerous filaments to supply these muscles, and the levatores costarum; that of the first sending a few filaments to the cervicalis ascendens, trachelo-mastoid, transversalis colli, and scaleni muscles.

The internal branches wind either over the posterior aspect of the semispinalis dorsi, or between it and the multifidus spinæ, and having supplied these muscles with numerous filaments, reach the sides of the spinous processes; here they perforate the rhomboid, latissimus dorsi, and trapezius, the last muscle very obliquely, and become cutaneous, being principally distributed to the skin at the back part of the scapular region.

The external branches of the four inferior pass obliquely downwards and outwards between the sacro-lumbalis and longissimus dorsi, communicating with each other in their course, and at the outer border of the former muscle perforate the tendon of the latissimus dorsi, and become cutaneous, some of the lower filaments being capable of being traced over the glutæal region.

The internal branches of the four inferior are remarkably small, and are lost either in the substance of the multifidus spinæ, or semispinalis dorsi. The cutaneous filaments from the posterior branches of the dorsal nerves given off on the one hand from the internal, and on the other from their external divisions,

are situated somewhat in a line with the angles of the ribs, so that they become more external in proportion to their inferior position.

The posterior branches of the lumbar nerves are analogous in their distribution to the four lower dorsal branches, having an external large musculo-cutaneous, and small internal muscular divisions. *The external branches* run along the deep surface of the longissimus dorsi, and at its outer edge perforate the tendon of the latissimus dorsi, and terminate in cutaneous filaments directed over the crest of the ileum to the glutæal region, as far as on a level with the great trochanter. *The internal branches* are lost in the substance of the multifidus spinæ.

The posterior branches of the sacral nerves exist as distinct branches within the spinal canal, and consequently differ from the cervical, dorsal, and lumbar, which become distinct trunks after the main trunks have issued from the spinal or intervertebral foramina. They decrease in size from above downwards, being extremely small, and passing out of the posterior sacral foramina, the fifth coming out between the sacrum and coccyx. They form a minute anastomosis with each other, and with the corresponding branch of the last lumbar, and after having given filaments to the lower part of the erector spinæ, perforate the tendon of that muscle, and are distributed to the skin over the sacrum and coccyx, and immediately around the anus.

The anterior branches of the spinal nerves are much larger than the posterior branches, the two upper cervical forming the only exception. They form intricate plexuses in the neck, the lower part of the spine and sacrum, the nerves given off from those in the first situation being principally intended for the neck and upper extremities; in the two last for the lower extremities. The intervening series represented by the thoracic nerves, being comparatively simple in their distribution, do not form plexuses.

The Anterior Branches of the Cervical Nerves.

The anterior branch of the first cervical nerve, smaller than the posterior, is directed between the occipital bone and the transverse process of the atlas, passes over the outer edge of the vertebral artery, and appears at the inner side of the rectus capitis lateralis. It then descends, and forms an anastomotic arch with the anterior branch of the second, in front of the transverse process. In its course the rectus capitis lateralis, and rectus capitis anticus minor receive one or more filaments, and it also sends a filament into the canal for the vertebral artery, and which communicates with the trunk of the second cervical between the transverse processes of the atlas and axis. From this anastomotic arch are given off filaments which communicate with the lingual and par vagum and superior cervical ganglion of the sympathetic.

The anterior branch of the second cervical nerve, also much smaller than the posterior passes forwards between the transverse processes of the atlas and the axis, being concealed by the levator anguli scapulæ, splenius, and first inter-transverse muscle, and divides into an ascending branch, passing in front of the transverse process of the atlas, to communicate with the first cervical; and a descending branch.

The descending branch soon subdivides, and gives several filaments of communication with the superior cervical ganglion; one small filament to communicate with the par vagum, another enters the rectus capitis anticus major, and the last concurs to form the cervical plexus.

Anterior branch of the third cervical nerve, larger than the posterior, and twice as large as the preceding, passes between the vertebral artery and inter-transverse muscles, and having given branches to the levator anguli scapulæ and rectus capitis anticus major, communicates above with the descending branch of the second, below with that of the fourth, and in the interval with the superior cervical ganglion, and then again bifurcates to enter into the formation of the cervical plexus.

The anterior branch of the fourth cervical nerve, of the same size as the preceding, communicates above with the third, below with the fifth cervical, in the middle with the superior cervical ganglion, and then enters into the formation of the lower part of the cervical plexus.

The cervical plexus (the deep cervical plexus) is composed of the primary and secondary anastomosing arches of the anterior branches of the four upper cervical nerves. These anastomosing arches are subject to considerable variation, though generally formed by each nerve bifurcating, and, after having communicated with the nerve above and below, again reuniting in a more or less uniform manner prior to giving off their terminal branches. The plexus is situated deeply at the upper anterior and outer part of the neck behind the posterior edge of the sterno-mastoid, in front of the scalenus posticus, external to the rectus capitis anticus major, the carotid artery, jugular vein, and par vagum. It constitutes the chief contents of the posterior superior cervical triangle, and is surrounded by a large quantity of loose cellular membrane, absorbent glands, and fat, and immediately invested with a prolongation of the deep cervical fascia, which renders the dissection of the numerous branches as they immediately proceed from it, difficult. It communicates internally by several delicate filaments with the superior and middle cervical ganglia of the sympathetic; below with the upper part of the brachial plexus, and externally with the spinal accessory, giving several filaments to the muscles with which it is in immediate relation. The branches given off from the cervical plexus may be divided as follows, into

$$\text{Superficial ascending}\ \begin{cases}\text{Superficialis colli.}\\ \text{Auricularis magnus.}\\ \text{Occipitalis minor.}\end{cases}$$

Superficial descending	Supra-clavicular. Supra-acromial.
Deep - - -	Communicating branches. Muscular. Phrenic.

The superficialis colli (superficial cervical nerve) takes its origin from the middle of the plexus in company with, but anterior to the great auricular, the anastomosing branches of the second and third cervical nerves concurring to form it. It emerges from behind the posterior border of the sterno-mastoid about the middle of the neck, and is directed horizontally forwards and inwards, behind the external jugular vein, and between the sterno-mastoid and platysma, and at a variable point divides into two branches, an ascending and descending, the former larger than the latter.

The ascending branch almost immediately divides into numerous filaments, some of which supply the platysma myoides; one or two ascending along the external jugular vein. The greater number are directed upwards and forwards to the upper part of the platysma and digastric muscle, communicate with the deeper seated filaments given off from the portio dura, and becoming cutaneous, supply the skin over the region of the sub-maxillary gland, the chin (communicating with the submental nerve), and the lower part of the cheek; some filaments being directed to the median line to communicate with the corresponding nerve of the opposite side.

The descending branch forms a loop, the concavity of which looks upwards and inwards, perforates the anterior part of the platysma, a little above the middle of the neck, gives off one or two twigs to accompany the anterior jugular vein, and terminates in the skin about the hyoid bone.

The auricularis magnus (the auricular nerve) arises in common with the trunk of the superficial cervical from the anastomosing branches between the second and third cervical. It emerges from behind the posterior border of the sterno-mastoid, above the superficial cervical, and in front of the occipitalis minor. It winds round the edge of the sterno-mastoid, and is directed along it obliquely upwards and inwards to the lower part of the parotid gland on a level with the angle of the jaw, reaches to the anterior border of this muscle, and divides into *a superficial and deep terminal branch.* It gives off before dividing several filaments between the parotid gland and the skin, and others which pass through the substance of the former to terminate in the skin in the malar region, where it communicates with the facial nerve.

The superficial branch courses upwards in the parotid fascia, and on a level with the antitragus divides into several filaments, which are distributed on the one hand to the concave surface of the auricle, particularly the concha; and on the other, to the anterior border of the helix, and the vertical groove in front of it.

The deep branch (anterior mastoid), having perforated the parotid gland, and crossed the auricular branch of the facial, with which it communicates, becomes placed behind the auricle of the ear, ascends along the anterior part of the mastoid process, communicates with the occipitalis minor, and terminates by supplying the skin at the back of the ear, some filaments passing on to its upper border.

The occipitalis minor (mastoid, external occipital) comes from the posterior part of the cervical plexus, taking its origin from the second cervical. It appears at the posterior edge of the sterno-mastoid, behind and above the great auricular. It passes upwards parallel with the great occipital nerve directed by the border of the splenius, which it occasionally perforates, to the occipital region behind the mastoid process; communicates with the great auricular externally, and with the great occipital nerve internally, and ends by terminating in the skin over the parietal bone. There occasionally occurs a small accessory nerve, between the auricularis magnus and occipitalis minor. This is directed along the posterior border of the sterno-mastoid, and is distributed to the skin over the mastoid process.

The supra-clavicular and acromial nerves, form the termination of the cervical plexus, and exist as two primary trunks, which usually about the level of the posterior belly of the omo-hyoid, divide and subdivide into numerous branches, which traverse superficially the posterior inferior triangle of the neck, first passing behind the platysma, then between it and the skin. The internal series (*sternal*) are directed forwards and inwards, over the lower part of the sterno-mastoid, the inner third of the clavicle, and end in the skin over the upper part of the sternum, and upper and inner part of the pectoralis major. The middle filaments (*mammary*) pass over the centre of the clavicle, and are distributed to the skin of the pectoralis major and the mammary gland, and communicate with branches of the intercostal nerves. The posterior (*clavicular*) pass downwards and outwards over the outer third of the clavicle, and ramify in this skin over the anterior and outer part of the deltoid.

The acromial nerves are larger than the clavicular, and are, ordinarily, two in number. They pass obliquely outwards, downwards, and backwards, over the lower part of the superficial aspect of the trapezius, give some filaments to this muscle, which communicate with the spinal accessory nerve, and having reached the acromion, divide into numerous cutaneous branches, which are lost in the skin covering the spine of the scapula, and the outer and back part of the deltoid.

The communicating branches have been already partly described in the consideration of the formation of the plexus; and are formed by different filaments, which are connected with the trunk of the sympathetic, its upper and middle cervical ganglion, as also with the par vagum and lingual. The internal deep branch is represented by the *communicans noni* or *internal descending cervical.* It takes

its origin principally from the descending division of the second cervical, and having received a filament from the first cervical, comes down the neck external and posterior to the internal jugular vein. At the middle or lower third of the neck, it describes a curve; the concavity of which looks upwards, and communicates with the descending branch of the lingual (descendens noni), by winding in front of the internal jugular vein. This nerve is subject to considerable variation, bifurcating, occasionally, before communicating with the descendens noni, and giving off now and then one or two delicate filaments to the same muscles, usually supplied by the latter nerve: viz. the sterno-hyoid, sterno-thyroid, and omo-hyoid. The external communicating branches are represented by a rather larger *anastomotic branch*, which communicates at an acute angle with the spinal accessory; and by the *muscular branches*. These accompany the spinal accessory, communicate more or less with it, and are distributed to the trapezius, levator anguli scapulæ, the rhomboideus minor, and upper part of the rhomboideus major.

The phrenic nerve (diaphragmatic, internal respiratory) appears at the lower and anterior part of the fourth cervical nerve of which it appears the continuation. It receives, however, some accessory filaments from the third and fifth cervical, which exist either as single or plexiform twigs, or are occasionally absent. The secondary sources of origin are, in fact, subject to considerable variation. It is directed along the anterior edge of the scalenus anticus, inclining slightly inwards between the subclavian artery and vein, before entering the superior opening of the thorax. It passes behind and outside the carotid artery and jugular vein, and communicates with the fifth, sixth, and, occasionally, with the seventh cervical and pneumogastric nerves, and invariably with the sympathetic. The exact points of communication of these different nerves is by no means determinate; sometimes taking place in the neck; at others, in the upper part of the chest. It crosses the direction of the internal mammary artery, and reaching the anterior mediastinum, glides down in front of the root of the lung between the pericardium and inner aspect of the former, and terminates in the diaphragm. In its course within the chest, it gives several filaments to the remains of the thymus gland; some very minute twigs of communication with the superior cardiac plexus; and receives, occasionally, a very delicate filament of communication, coming down obliquely, from the descendens noni: on reaching the diaphragm, the nerve divides into a series of superior and inferior filaments; the former, long and diverging from each other, enter the upper surface of the muscle, having first passed for some distance between the muscle and the pleura covering it; the latter perforate the muscle, diverge, and run for some distance between the muscle and peritoneum, and enter its under surface.

The right phrenic is shorter and more vertical in direction, and more anterior in its position than the left, being directed in the upper part of the chest, along the vena cava superior. Several of its internal terminal filaments pass behind the vena cava inferior, communicate with the left, and end in the cœliac plexus; a few, however, communicate, also, with some twigs of the pneumogastric.

The left phrenic turns over the apex of the heart; and, besides its general distribution, gives filaments to the crura of the diaphragm, anastomosing filaments to the solar and cœliac plexus, and some communicating branches to the opposite nerve.

The anterior branches of the four inferior cervical and first dorsal nerves are very large, and form, therefore, a remarkable contrast to the four upper cervical, situated above them. They pass through the intervertebral foramina, between the two scaleni; the eighth cervical passing between the foramen common to the last cervical and first dorsal vertebra. Having given off several filaments to communicate with similar filaments from the inferior and middle cervical ganglion, and some small twigs to the scaleni, the different branches unite together, so as to constitute the brachial plexus; the first, communicating above with the fourth cervical, and sending a twig to the phrenic. The union of the different branches takes place in the following manner: — the anterior branches of the fifth and sixth descend obliquely outwards, and, after a course of about one or two inches, unite at an acute angle. Those of the eighth cervical and first dorsal, which are not so oblique in their direction, similarly unite; but a little more internally: this union taking place, occasionally, between the scaleni, either pair of branches almost immediately bifurcating after their union. The trunk of the seventh passes distinct between the two upper and lower branches, as far as the lower border of the clavicle in the upper part of the axilla, and there bifurcates; the upper part of the bifurcation being connected with the lower part of the bifurcation of the first united cord, and the lower with the upper of the last united cord. Secondary bifurcations and anastomoses take place at more or less acute angles, and thus the brachial plexus is constituted.

The brachial plexus (axillary) is situated at the inferior and lateral part of the neck, in the posterior inferior cervical triangle, where it is covered in by a considerable quantity of fat, cellular membrane, and lymphatic glands, which separate it from the external jugular vein. The scalenus anticus bounds it in front and internally; the scalenus posticus in the opposite direction; and in its course from between these muscles to the clavicle, it is crossed by the omo-hyoid muscle, transversalis coli, and humeral vessels, and more superficially, by the supra-clavicular and acromial branches of the cervical plexus. Having passed from beneath the clavicle, it becomes placed between the coracoid process of the scapula and the first digitation of the serratus magnus,

and anterior and external to the first rib, and there divides into its terminal branches. In the neck, the plexus is situated superior, posterior, and external to the artery; but as the trunks gradually converge towards the axilla, and the terminal branches again diverge, the artery comes to be bounded by some internally, by others externally. The plexus is broad above, where it represents the base of a triangle, and narrow below at its termination at the upper part of the axilla.

The different branches of the plexus may be divided into those given off above, and those below the clavicle: — the former, for the levator anguli scapula, subclavius, rhomboid, and serratus magnus; the latter, for the upper extremity and its muscles.

Supra-clavicular	Muscular, supra-scapular. Subscapular.
Infra-clavicular	Internal cutaneous. External cutaneous. Median. Ulnar. Musculo-spiral. Circumflex.

Of the muscular branches. *The nerve for the rhomboideus* takes its origin from the anterior branch of the fifth cervical, immediately after it has quitted the intervertebral foramen; but is frequently given off from the cervical plexus: it is, consequently, deeply seated. It either perforates the scalenus porticus or winds round it, to get between it and the levator anguli scapulæ; continues along the costal surface of the latter muscle, and then passes to the same surface of the rhomboideus, as far as its lower part, frequently supplying, in its course, the levator anguli scapulæ, which, in many cases, however, receives filaments from a distinct nerve arising above it, and taking a similar course.

The nerve to the serratus magnus (external respiratory, posterior thoracic), situate at the posterior and upper part of the plexus, arises from it by two delicate roots, which come off from the lower edge of the fifth and sixth cervical, immediately after they have passed the intervertebral foramina. It receives, sometimes, a twig from the seventh. It is directed downwards and outwards, and reaches the thorax between the subscapularis and serratus magnus, passing behind the axillary vessels. It passes along this muscle inferior, to the long thoracic artery, and terminates in its lower part, by numerous filaments.

The nerve for the subclavius is very small, but always present, and is given off from the anterior part of the united trunk of the fifth and sixth cervical. It passes down anterior to the subclavian artery, and enters the middle of the muscle.

The remainder of the muscular branches are very small, and come off from the lower and anterior part of the plexus, being principally derived from the seventh cervical: some pass behind, and others, in front of the axillary artery, enter the axilla, and are distributed to the posterior surfaces of the pectoralis major and minor. They are known under the collective name of *anterior or short thoracic.*

The supra-scapular nerve, larger than the long thoracic, issues from the upper and back part of the plexus, from the united root of the fifth and sixth cervical at their angle of union. It is directed downwards, outwards, and backwards in company with the supra-scapular vessels, passes behind the trapezius and coracoid process to the notch in the upper edge of the scapula, beneath the ligament which converts this notch into a foramen, and which separates it from the supra-scapular vessels. Having reached the supra-spinal fossa, and supplied the supra-spinatus muscle, it winds along the concave external border of the spine, and reaches the infra-spinal fossa, supplying the infra-spinatus. From the inferior filaments one or two twigs can be traced to the teres minor.

The subscapular nerves are intended for the latissimus dorsi, teres major, and subscapularis. That for the first muscle is the largest and longest. It arises from the plexus above, and internal to the circumflex nerve, passes down in the axilla between the subscapularis and serratus magnus, parallel, but posterior to the long thoracic, and terminates by reaching the lower border of the latissimus dorsi, where it enters its substance. It gives off occasionally in its course the branch from the teres major, which usually, however, arises from the plexus below it. This nerve passes downwards and outwards at the subscapularis, and enters the anterior surface of the teres major.

The nerves for the subscapularis are: a small one, generally constant as to its origin arising high up from the same source of origin as the circumflex, passing behind the axillary artery to the upper part of the superficial surface of the subscapularis; the other larger, and frequently derived from the circumflex, to be distributed to the middle of the muscle.

The internal cutaneous, the smallest of the terminal branches of the brachial plexus, and situated most internally, takes its origin principally from the last cervical and first dorsal. It descends, covered in by the brachial aponeurosis, along the inner aspect of the arm, between the median and the ulnar, and concealed above by the axillary artery. Deeply seated in the axilla, in leaving this cavity it inclines slightly forwards and outwards in company with, but anterior to, the basilic vein; and at a variable distance from the elbow joint, generally a little below the middle of the arm, divides into *external and internal cutaneous branches*: both of which perforate the fascia. In this part of its course the internal cutaneous gives off in the axilla a small cutaneous filament, which, having communicated with the second or third intercostal nerve, perforates the fascia, and supplies the skin on the inner part of the arm as far as the internal condyle.

The external terminal branch, the continuation of the trunk in the arm, and the larger of the two, divides into two or three twigs, which pass either in front or behind the

median basilic vein, some occasionally passing in front, and some behind. The external filaments course down the anterior and inner part of the fore-arm, following the direction of the median vein, and communicating with branches of the external cutaneous: the internal follows the course of the ulnar vein, communicating with a twig of the ulnar nerve at the lower part of the fore-arm. Both terminate in the integument over the annular ligament.

The internal branch, frequently perforating the fascia lower down than the external, passes behind and then below the median basilic vein, to the inner and back part of the fore-arm, and having communicated a little below the elbow with the accessory internal cutaneous, continues its course, and supplies the integument along the inner and back part of the fore-arm as far as the inner edge of the hand, communicating, in its course, with the innermost filaments of the external branch.

Placed behind and internal to the internal cutaneous nerve, is the *cutaneous nerve of Wrisberg* (the accessory nerve of the internal cutaneous), considerably smaller than it. It arises from the united chord formed by the seventh cervical and first dorsal. It descends along the inner part of the axilla, and communicates with the cutaneous branch of the second intercostal. Coursing down the arm on a plane behind the ulnar and internal to the basilic vein, it perforates the fascia about the lower third, and, becoming cutaneous, divides into anterior filaments, communicating with the internal cutaneous: and posterior, communicating with the internal cutaneous branch of the musculo-spiral.

The external cutaneous (musculo-cutaneous: perforans casserii), larger than the preceding, but smaller than all the other nerves, and most external, is formed by the fifth and sixth cervical. It is directed obliquely downwards and outwards in front of the tendon of the subscapularis to the inner aspect of the coraco-brachialis, perforates this muscle (occasionally, however, passes behind it without perforating), and then becomes situated obliquely between the biceps and brachialis anticus. At a short distance from the elbow it emerges from beneath the outer border of the biceps, and internal to the supinator longus; and at the bend of the elbow, after passing behind the median cephalic vein, becomes subcutaneous. In this part of its course the external cutaneous nerve gives off a series of muscular branches. Of the two *branches to the coraco-brachialis*, the upper, having perforated it, terminates in the short head of the biceps.

The branches to the biceps unite separately or by a common trunk, and one of them perforates the biceps, and supplies the elbow-joint, being here situated to the outside of the superficial flexor tendons.

The branches for the brachialis anticus are several, and penetrate the muscle by its superficial surface. The continuation of the external cutaneous nerve in the fore-arm is represented by a series of *internal and external cutaneous branches*, which pass down along either side of the radial vein. *The former* near the wrist joins with a branch from the radial nerve, and gives off a filament which perforates the fascia, and accompanies the radial artery to the outer and back part of the wrist, where it supplies small twigs to the front and back of the radio-ulnar articulation. *The latter* gives filaments to the outer and back part of the fore arm, as far as the wrist.

The median nerve. — The largest of the brachial plexus, and situated between the external cutaneous and the ulnar, arises by two roots, the external common to the median, and the external cutaneous: the internal common to the median, the internal cutaneous, and the ulnar. The fifth, sixth, seventh, and eight cervical and first dorsal nerves consequently concur to form it. Between its two roots is placed the axillary artery. It passes along the inner side of the arm in company with the axillary artery to the bend of the elbow, lying at first to the outside of the vessels, and then a little above the middle of the arm, crosses to its inner side, occasionally, however, continuing all along to its outside. It is slightly overlapped by the inner border of the biceps, having the brachialis anticus to its outside: the latter muscle separates it inferiorly from the ulnar nerve. The upper part of the internal cutaneous nerve runs along its inner side. It sinks into the bend of the elbow behind the semilunar fascia, and in front of the brachialis anticus, passes between the two heads of the pronator radii teres, and is then conducted along the forearm between the flexor digitorum sublimis and profundus to the annular ligament, behind which it passes; and at the lower border of this becomes expanded, and divides into a series of terminal digital branches.

The median nerve gives off no branches during its course along the arm, with the exception of an occasional communicating branch to the musculo-cutaneous below the level of the insertion of the coraco-brachialis; and a branch which is usually found coming off from the anterior part of the trunk a little above the elbow. This is directed along the brachialis anticus to the pronator teres, which it supplies, and sends a few filaments backwards to enter the articulation.

The branches given off in the fore-arm are muscular, interosseous, and cutaneous.

The muscular branches for the lower part of the pronator teres, flexor carpi radialis, palmaris longus, and flexor sublimis, are generally derived from a primary branch, which arises behind the pronator teres a little below the elbow-joint; the lower part of the flexor sublimis, however, receiving several smaller branches from the main trunk. The branches for the flexor longus pollicis and flexor digitorum profundus are given off lower down, there being generally one for the former and two for the latter, the outer part of which only is supplied; the inner part of the muscle being supplied by the ulnar nerve.

The anterior interosseous nerve is the most

deeply seated branch of the median, coming off at an acute angle from the trunk, between the origin of the deep-seated muscular branches. It runs vertically downwards in company with, but to the radial side of, the corresponding artery, in front of the interosseous membrane between the flexor digitorum profundus and flexor longus pollicis, giving on either side small filaments to them. Having reached the upper edge of the pronator quadratus, it passes behind that muscle, and terminates either by sending numerous filaments into its posterior surface, or, after having supplied it, perforates the lower aperture of the interosseous membrane, and reaches the back of the carpus.

The palmar cutaneous branch is given off at the lower fourth of the fore-arm, passes forwards from beneath the tendons of the flexor sublimis, and behind the fascia, which it perforates a little above the wrist, and divides into an external filament, which, having communicated with the radial, terminates in the skin of the vola major, and an internal descending over the annular ligament to be lost in the skin of the upper part of the palm.

The terminal digital branches of the median are derived from two primary branches, into which the flattened and expanded nerve divides, after having passed from beneath the annular ligament. These are external and internal, the former supplying the muscles of the thumb, and sending off three digital branches for the thumb and radial side of the index finger, and rather smaller than the latter, which gives off two digital branches for the opposed sides of the index and middle, and the middle and ring finger. The *muscular branch* passes in a slightly curved manner outwards and upwards, and terminates in filaments for the supply of the abductor, opponens and flexor brevis pollicis.

The first digital nerve is directed obliquely downwards and outwards in front of the tendon of the flexor longus pollicis, and near the head of the metacarpal bone, crosses it to its outer side, and continues its course to the extremity of the outer side of the anterior aspect of the first phalanx, where it terminates in dorsal and palmar branches. The dorsal branch winds on to the back of the last phalanx, communicates with the radial, and supplies the skin at the root of the nail; the palmar continues in the original course of the nerve to the skin at the extremity of the thumb.

The second digital nerve, not so oblique in its direction as the first, crosses over the adductor pollicis, gives a filament to it, and is conducted along the inner side of the flexor longus pollicis tendon to the ulnar side of the thumb, sending in its course some filaments backwards to communicate with the dorsal branches of the radial, and terminating in a similar manner to the preceding branch.

The third digital nerve is directed in front, and to the outside of the first lumbrical muscle, gives a filament to it, and reaches to about the middle of the outer side of the proximal phalanx of the index finger, where it divides into dorsal and palmar branches. The dorsal branch passes on to the back of the phalanx, communicates with one of the dorsal cutaneous nerves, to form a nerve which ends in the integuments of the back part of the last phalanx: the palmar branch passes in the original direction of the nerve, and terminates on the outer side of the distal phalanx by again dividing into palmar and dorsal branches, having a similar distribution to the two first nerves.

The fourth digital nerve passes in front of the second interosseous space, gives a filament to the second lumbrical muscle, and about the middle of this space divides into two branches, which are directed along the opposed sides of the middle and index fingers. The *fifth* passes downwards and slightly inwards in front of the third metacarpal space, gives a filament to the third lumbricus, communicates by a delicate filament with the ulnar, and at the middle of this space terminates in two branches for the opposed sides of the middle and ring finger. The termination of the divisions of the fourth and fifth digital nerves, and the branches given off from them, are exactly similar in distribution to the third digital nerve, giving off, like it, on the proximal and distal phalanx, a dorsal branch. Each of the digital nerves, although running along the sides of the fingers, and giving off in their course numerous cutaneous filaments, which are directed towards the axes of the fingers, are not observed to anastomose with each other.

The median nerve in the palm of the hand is situated on a plane anterior to all the flexor tendons, and the trunk before dividing is situated half an inch or more above the level of the superficial palmar arch of arteries which crosses in front of its three internal branches. The accompanying digital arteries are placed somewhat behind, and further from the longitudinal axes of the fingers than the nerves, which, however, in their course send numerous small filaments which wind around them.

The ulnar nerve, somewhat smaller than the median, arises from a trunk common to it, the internal cutaneous and the inner head of the median. The first dorsal and last cervical are consequently principally engaged in forming it. Almost immediately after its origin it is directed slightly inwards and outwards from the median, and behind the internal cutaneous, and at the lower part of the axilla appears deeply seated at the inner aspect of the arm, being directed in front of the triceps extensor muscle. Below the level of the coraco-brachialis it perforates the internal intermuscular septum, and becomes surrounded by several fasciculi, derived from the inner head of the triceps, and passes behind the intermuscular septum to gain the space between the internal condyle and olecranon, being here situated between the two heads of the flexor carpi ulnaris. It now inclines downwards and slightly outwards along

the inner part of the coronoid process of the ulna, and then takes a vertical course down the fore-arm, covered over by the flexor carpi ulnaris, and between it and the flexor digitorum profundus. It gradually inclines to the surface, and at the lower third of the fore-arm becomes sub-aponeurotic, and passes from between the flexor carpi ulnaris and inner tendon of the flexor sublimis to the lower part of the anterior surface of the annular ligament, passing along it in a distinct sheath with the artery, in close contact with, and external to, the pisiform and unciform bones, and divides into its terminal branches. In the upper part of the arm the ulnar nerve is in relation with the axillary artery, which is placed between it and the median, nearer however the latter. In the upper part of the fore-arm it is about half an inch or more distant from the artery, but gradually inclines, so as to come in close relation with, but internal to it, in the two lower thirds of the fore-arm, and in the palm of the hand.

The ulnar gives off no branches in the arm; and the first that comes off from it, is when the nerve is placed between the two heads of the flexor carpi ulnaris. There are several small articular filaments which enter the inner part of the joint, and three or four which are distributed to the above muscle. In the upper third of the fore-arm some filaments are again given off to the flexor carpi ulnaris, and others for the supply of the inner half of the flexor digitorum profundus. About the middle a small branch is given off, which, after sending satellite filaments to accompany the ulnar artery, perforates the fascia, and becomes cutaneous to communicate with the internal cutaneous. The largest branch, however, given off from the ulnar, comes away about two inches above the wrist-joint, and is named, its *dorsal branch* (dorsalis carpi ulnaris: internal dorsal nerve). This winds downwards and inwards, and having passed between the tendon of the flexor carpi ulnaris and the bone, perforates the fascia at the back of the fore-arm, and becomes cutaneous a little above the styloid process. It runs then along the inner edge of the carpus; and on the posterior annular ligament terminates in two branches. The *inner branch* passes along the inner and back part of the metacarpal bone, and phalanges of the little finger, supplying the integument as far as its extremity, and sending in its course some small filaments to the abductor minimi digiti. The *outer branch* crosses obliquely the tendon of the extensor minimi digiti, and on the fourth interosseous space sub-divides. The inner sub-division at the extremity of the space bifurcates in order to supply the opposed sides of the little and ring finger. The outer sub-division at the lower extremity of the third interosseous space having communicated with the dorsal branch of the radial, similarly bifurcates for the supply of the integument of the opposed sides of the middle and ring finger. The dorsalis carpi ulnaris, independently of the above branches, sends numerous filaments to the inner and back part of the wrist and hand, and communicates above with the external or posterior cutaneous.

The terminal branches of the ulnar nerve are two in number, *a superficial external, and deep internal.*—The former, after a very short course, divides into two branches, a small internal, and large external. The *internal branch* passes along the ulnar side of the little finger to its extremity, giving filaments in its course to the muscles of the little finger. The *external* passes obliquely across the flexor tendons for the ring finger, gives a filament to the fourth lumbricus, and one of communication with the median, and over the fourth interosseous space at a variable distance from its inferior extremity bifurcates: the divisions of the bifurcation being distributed in a similar manner with the median to the opposed surface of the ring and little finger.

The deep branch is directed backwards and outwards between the abductor minimi digiti, and the flexor brevis to the posterior aspect of the adductor minimi digiti, having first given off on the palm a small branch which sends filaments to these three muscles. It passes downwards in a curved manner, the convexity of the curve looking downwards and inwards, and after a short course passes at an acute angle behind the deep palmar arch of arteries. No branches come off from its concavity. From its convexity and back part and outer termination are derived filaments which supply the two inner lumbricales, the palmar and dorsal interossei, the adductor and flexor brevis pollicis. The deep or perforating interosseous branches can be traced through the two layers of interossei to the skin on the back of the hand, where they communicate with the dorsal cutaneous from the radial and ulnar nerves.

The musculo-spiral nerve (*radial*) slightly larger than the median, arises from the inner and back part of the plexus, and is formed particularly by the three inferior cervical and first dorsal nerves. The trunk from which it arises also gives origin to the circumflex nerve. It passes at first from before backwards, running behind the ulnar, and in front and below the circumflex nerve, and having crossed the conjoined tendons of the teres major, and latissimus dorsi, inclines downwards, backwards and outwards to the posterior surface of the humerus, between it and the long head of the triceps. It continues gradually inclining more outwards, till it reaches the lower third of the arm where it gains the outer aspect of the bone, and here it passes forwards in company with the superior profunda artery, to the anterior and outer aspect of the arm lying internal to the outer head of the triceps which it perforates. It is now directed between the supinator longus and brachialis anticus, and then between the latter and extensor carpi radialis longior, and, having reached the outer and anterior part of the elbow-joint, divides into an anterior and posterior terminal branch.

The branches given off from the musculo-

spiral in the arm are numerous, and may be arranged into

Internal	Internal cutaneous. Branch for the internal head of the triceps.
Posterior	Branches for the long head of the triceps. Outer head and anconæus.
External	Cutaneous filaments to the arm. External cutaneous.

The internal cutaneous is the first branch of the musculo-spiral, and continues for some distance deeply seated to the fascia, which it perforates above the middle of the arm, and descends as one or two filaments along the inner and back part of the arm to the elbow, where they communicate with the posterior filaments of the accessory internal cutaneous.

The branch for the internal head of the triceps is the next that is given off. It is a delicate, long nerve, which is directed along the surface of the inner portion of the triceps, running behind the ulnar nerve to within three or four inehes of the elbow-joint, when it enters the substance of the muscle.

The branches for the long head of the triceps are numerous, and enter its anterior surface. The superior branch is reflected upwards, and can be traced as far as the axillary origin of the muscle. The inferior or descending branch is the longest, and courses downwards to near the olecranon before entering it.

The branch for the outer head of the triceps and anconæus, given off externally to the branches for the long head, is a long slender nerve. It passes down between the outer and middle head to the outside of the olecranon, supplying the outer head in its course, and terminating in the anconæus by entering at its anterior surface.

The external cutaneous branch is given off below the middle of the arm, as the musculo-spiral is commencing its anterior and outer course. It passes along the outer and back of the arm, and divides into two or three delicate descending filaments which supply the skin, and terminate on the back of the carpus between the posterior branches of the external cutaneous, radial, and dorsalis carpi ulnaris with which they communicate.

The musculo-spiral nerve, before giving off its terminal branches, sends filaments to the muscles between which it passes, viz. the brachialis anticus, supinator longus, and extensor earpi radialis longior.

The anterior terminal branch (*radial nerve*) is the apparent continuation of the musculo-spiral nerve, though smaller than the posterior terminal branch. It passes between the supinator longus and brevis, lying on the latter, and over-lapped by the former, and gradually approaches, in its descent of the fore-arm, the radial artery; so that at the middle it is in close contact with, but external to, the vessel. Having arrived at the lower third of the fore-arm, or a little above, it twists round the deep surface of the tendon of the supinator longus, and appears beneath the fascia on the outer part of the fore-arm, and after a short subaponeurotic course, perforates the fascia, and divides about a couple of inches above the styloid process into *an external large, and internal terminal-branch. The external branch* passes along the outer aspect of the styloid process; and at the proximal part of the wrist sends a communicating loop inwards, to be connected with the cutaneous palmar branch of the median. It then descends on the dorsum of the thumb, and supplies its external border. *The internal branch* crosses obliquely the extensor ossis metacarpi and primi internodii pollicis, and divides into a series of branches which supply the ulnar side of the thumb: both sides of the index finger, and the radial side of the middle. These different branches furnish, in their course along the carpus, several cutaneous filaments, and some small twigs which communicate with the perforating interosseous of the deep branch of the ulnar nerve. The most internal division communicates with the dorsalis carpi ulnaris. The two terminal branches of the radial are subject to much variation: the external being sometimes larger than the internal, and supplying either both sides of the thumb, or both sides of the thumb and the radial side of the index finger. The internal branch occasionally unites with the outer division of the dorsalis carpi ulnaris, and supplies the opposed sides of the middle and ring fingers.

The deep terminal branch (*the posterior interosseous or muscular*) is larger than the anterior, passes downwards and backwards along the inner aspect of the exterior carpi radialis brevis, gives filaments to it, and reaches the surface of the supinator brevis, supplies it, as it passes obliquely downwards, backwards, and inwards through its substance, to emerge at its lower and posterior portion. It here divides into a posterior and anterior series: the former supplying the extensor carpi ulnaris, the communis digitorum, and minimi digiti, entering at their anterior aspect the latter the deep-seated muscles. One of the latter has a somewhat remarkable course; is longer and larger than the rest; and passes along the posterior surface of the extensor ossis metacarpi and primi internodii; and at the lower part of the fore-arm becomes placed between the interosseous ligament and the extensor secundi internodii, and indicator, supplies these muscles with one or two twigs, and is conducted in front of the posterior annular ligament to the back of the carpus, where it assumes a gangliform enlargement, from which numerous filaments radiate for the supply of the ligaments and carpal articulations.

The circumflex nerve (*axillary*) is the most posterior of the terminal branches of the brachial plexus, and is occasionally given off from the musculo-spiral, usually, however, taking its origin from a trunk common to it, and to that nerve, external to which it is situated. After a short course in the axilla, it soon leaves that space by passing downwards and outwards over the upper part of the axillary border of the subscapularis to enter the quadrilateral space above the teres major, below the

teres minor, and between the humerus and long head of the triceps to terminate in the deep surface of the deltoid. It gives off in this course branches to the subscapularis and teres minor; that for the latter entering the lower border of the muscle, and prior to dividing into its deltoid branches. — *The cutaneous nerve of the shoulder* passes from behind the posterior border of the deltoid, perforates the fascia, and divides into a series of radiating branches, which supply the skin at the upper and back part of the shoulder. *The deltoid branches* ramify through the substance of the muscle as far as its insertion, and from one of them a filament is given off to the capsular ligament of the shoulder joint.

The anterior branches of the dorsal (intercostal) nerves are twelve in number, the first escaping between the first and second dorsal vertebræ, and the last between the last dorsal and first lumbar. They run more or less parallel to each other without forming plexuses, and are destined to supply the thoracic and abdominal parietes, and the skin about the arm and axilla. They present general and special characters. Each branch runs outwards, from its origin, being separated from the posterior root by the intervention of the anterior costo-transverse ligament, to reach the intercostal space, between the pleura and external layer of the intercostal muscles, and below the intercostal vessels. Having communicated by one or two filaments with the thoracic ganglia of the sympathetic, these nerves are continued between the two layers of the intercostals, to about midway between the spine and the sternum, and here they divide into *cutaneous* and *intercostal* branches. The cutaneous branches perforate, in a very oblique manner, the external layer of intercostals; and, after a short course, forwards and outwards, between them and the serratus magnus, either escape between the digitations of the serratus magnus and external oblique, or perforate their fibres, and divide into anterior and posterior branches. This division takes place sometimes when the trunks of the cutaneous nerves are covered by the serratus and oblique. *The posterior branches* are reflected backwards and upwards, and, after a course of an inch or two between the latissimus dorsi and the skin, terminate in the latter. *The anterior branches* are directed downwards and forwards, or horizontally, and, after a longer course than the posterior branches, terminate, like them, in the skin.

The intercostal branches, though somewhat smaller than the cutaneous, represent the continuation of the anterior branches of the dorsal nerves. They continue in the original course of the latter, below the lower edge of the ribs on the one hand, and the costal cartilages on the other; and near the border of the sternum above, and the linea alba below, perforate the muscular fibres, and become cutaneous. The trunks of the intercostal nerves and their continuation give off numerous filaments to the supply of the intercostal muscles, and several extremely delicate twigs, which frequently pass over the inner aspect of the ribs, to communicate above and below with each other in the intercostal spaces.

The special characters of the intercostal nerves are as follow: —

The first dorsal nerve, ascending in front, and across the neck, of the first rib, to assist in the formation of the brachial plexus, gives off only a small intercostal nerve. This comes away soon after the nerve has left the intervertebral foramen, and is directed along the inner surface of the first rib, to the first intercostal space, without giving off a middle cutaneous branch, and passes along the lower edge of the cartilage to the sternum, by the side of which it perforates the intercostal muscles, and terminates on the skin, at the upper and fore part of the thorax.

The second dorsal nerve crosses obliquely over the second rib, external to its neck, to gain the lower part of the first intercostal space, and again crosses the second rib, to reach the second intercostal space on a level with the middle of the former. *Its cutaneous branch* is of large size, and, supplying the arm with cutaneous branches, is named the *intercosto-humeral*, which perforates the second intercostal space. In traversing the axilla it gives off a branch of communication to the accessory internal cutaneous, and one to communicate with the second intercosto-humeral; the latter united nerve sending filaments to the skin at the upper and anterior part of the arm. Two or three filaments represent the termination of the nerve, cross the lower part of the posterior boundary of the axilla, and terminate in the skin, at the upper and back part of the arm.

The cutaneous branch of the third dorsal (the second intercosto-humeral) is smaller than the second, and passes through the third intercostal space: it divides into an anterior and posterior branch; the former winds upwards, forwards, and inwards, over the lower border of the pectoralis major, to terminate in the mamma and integument; the latter, having communicated with the second intercostal, sends filaments to the axilla, and terminal branches, which are directed to the outer and anterior part of the axilla to supply the skin, at the upper and back part of the arm.

The cutaneous branches of the fourth and fifth dorsal nerves send filaments inwards, to supply the mamma; and filaments backwards, over the superficial surface of the latissimus dorsi, to supply the skin over the anterior and outer part of the scapula. The intercostal nerves of the eighth, ninth, tenth, *and eleventh dorsal nerves* perforate the intercostal spaces of the false ribs, pass through the costal attachments of the diaphragm, to get between the external and internal oblique, as far as the border of the rectus, where they give off small cutaneous branches. Entering the sheath of the rectus, they proceed along the posterior surface of the muscle, and terminate, by giving off some filaments, which ramify in its inner part; and others, which perforate the anterior

layer of the sheath, at a variable distance from the linea alba, to supply the skin at the anterior part of the abdomen.

The twelfth dorsal nerve is larger than those that have preceded it, and gives a filament of communication to the anterior branch of the first lumbar nerve. It is directed obliquely downwards and outwards, following the course of the last rib, along the lower border of which it runs, passes behind the anterior layer of the transversalis fascia between it and the quadratus lumborum, and, on a level with the apex of the rib, divides into two branches. *The cutaneous branch*, larger than the abdominal, or continuation of the trunk, perforates, obliquely, the external and internal oblique, gives them some small branches, and then becomes superficial, crosses over the crest of the ilium, and divides into a series of divergent filaments, which lose themselves in the skin of the middle of the glutæal region. *The abdominal branch or continuation of the nerve* passes between the internal oblique and transversalis, supplies these muscles, communicates with the first branch of the lumbar plexus, and terminates in the rectus and pyramidalis, and the skin over them.

The anterior branches of the lumbar nerves are five in number, intervening between the corresponding branches of the dorsal and sacral nerves. They increase in bulk from above downwards, communicate with each other by anastomosing branches, and with the lumbar ganglia by filaments, which come from the latter, or the main trunks. These filaments of communication with the sympathetic, vary in number from two to five, and are in close relation with the convexities of the bodies of the lumbar vertebræ. Several nerves are also given to the supply of the psoas muscle.

The anterior branch of the first lumbar nerve is small, much resembling the anterior branch of the last dorsal. Having quitted the intervertebral foramen, it immediately divides into three branches ; two external and small, viz. : — *the great and small musculo-cutaneous;* the other internal and vertical in direction, and forming *the anastomosing branch with the second.*

The anterior branch of the second lumbar nerve, twice as long and broader than the first, gives off the *genito-crural* and *external cutaneous*, and communicates by a long anastomosing branch with the third.

The anterior branch of the third lumbar nerve, nearly twice as large as the second, is directed downwards and outwards, and gives off, at an acute angle, a large external branch, concurring to form the *anterior crural*, and an internal, the *obturator nerve:* it communicates with the fourth nerve by one branch connected with the main trunk, or by two connected with its two branches.

The anterior branch of the fourth lumbar nerve is somewhat larger than the third. It divides into an external branch connected with the *external* division of the third, to complete *the anterior crural;* and *internal* to assist in the formation of the obturator. Its terminal branch is the anastomosing branch with the fifth, internal to the other two, and vertical in direction.

The anterior branch of the fifth lumbar nerve is the largest of all the series, and terminates in the sacral plexus, and is named the *lumbo-sacral nerve.*

The lumbar or lumbo-abdominal plexus is rather intricate, and formed by the anastomosis of the anterior branches of the five lumbar nerves. Placed upon the sides of the lumbar vertebræ between the transverse processes, and enveloped by the fasciculi of the psoas muscle, it presents, when the latter are dissected away from it, an irregularly triangular appearance ; the apex of the triangle being above, and the base below. In the former situation, the nerves forming it are comparatively delicate, and unite with each nearer the vertebral column than the latter ; it communicates above with the twelfth dorsal nerve, through the medium of the "dorso-lumbar," and below, with the sacral plexus, through the medium of the "lumbo-sacral" nerve. The branches given off from it may be divided into *abdominal* and *crural:* the former being given off from its upper ; the latter, from its inferior or terminal portion.

The abdominal series is represented by the *musculo-cutaneous nerves*, and *the genito-crural. The crural series* by the *external cutaneous, crural*, and *obturator*. The musculo-cutaneous nerves are two in number: the upper being three or four times larger than the lower.

The upper musculo-cutaneous (large abdominal, ilio-hypogastric, ilio-scrotal) is the highest of the branches of the lumbar plexus, taking its origin from the first lumbar nerve. It makes its appearance from behind the psoas muscle about an inch and a half below the last dorsal nerve, runs obliquely downwards and outwards across the quadratus lumborum in the subperitoneal tissue, and about an inch above the crest of the ilium, perforates the tendon of the transversalis, and is continued between it and the internal oblique to the middle of the crest of the ilium, where it divides into two branches, an external and internal. The external passes obliquely between the internal and external oblique, and at the anterior-third of the crest of the ilium, winding on to the glutæal region, divides into an anterior and posterior series of filaments ; the one supplying the integument over the tensor vaginæ femoris, the other that over the anterior part of the glutæus medius. The internal branch, or the continuation of the nerve, after a course of an inch or two, communicates with the small musculo-cutaneous by a loop which usually passes round the internal circumflex ilii vessels. It then divides into an abdominal and scrotal branch. The abdominal runs parallel to the corresponding branch of the last dorsal, generally communicates with it, and passes through the tendons of the internal and external oblique, and is distributed to the skin at the inner part of the groin. The *inguinal*,

pubic, or scrotal branch runs parallel to Poupart's ligament, in company with, but above, the small external cutaneous, reaches the external ring, and divides into internal terminal branches supplying the skin over the pubis; and external ones supplying the scrotum in the male, and the labia pudendi in the female.

The lower musculo-cutaneous (small musculo-cutaneous—small inguino-cutaneous—small abdominal) is a thin delicate nerve, arising generally from the first lumbar, sometimes from the large musculo-cutaneous, is directed downwards and slightly outwards, along the back part of the psoas, a little in front of the inner border of the quadratus lumborum, crosses the iliacus internus about its upper fourth, and reaches the anterior third of the crest of the ileum. There it is lost by communicating with the large musculo-cutaneous, or, as is generally the case, passes after this communication as a very delicate nerve between the internal oblique and transversalis, supplying the lower part of these muscles, but principally the latter, and parallel to Poupart's ligament, perforates the former muscle at the outer ring, and terminates in a manner similar to the pubic or scrotal branch of the upper musculo-cutaneous, in the scrotum and pubic integument.

The genito-crural nerve (external spermatic — internal inguinal) derived from the second lumbar nerve, and sometimes from the communicating branch between the first and second, passes directly forwards to the anterior part of the psoas muscle, along which it descends vertically to the femoral arch. It lies behind the spermatic vessels, and is crossed by the ureter. Having reached Poupart's ligament, it divides into two branches, an internal or genital, and an external or crural. The genital is directed across the external iliac artery (to which it supplies a few filaments) to the chord, lying below it as far as the internal ring. Prior to entering the inguinal canal the transversalis and internal oblique receive a few reflected branches from it. The nerve then accompanies the chord, crosses the epigastric vessels, supplies the cremaster muscle, runs immediately in front of Gimbernat's ligament, and terminates in the scrotal integument in the male, and labia pudendi in the female, supplying also the integument at the upper and inner part of the thigh, and communicating with the inferior pudendal nerve. The *crural branch* (femoral-cutaneous), having given off several delicate filaments to be distributed to the transversalis and internal oblique, crosses the circumflex ilii vessels, passes underneath Poupart's ligament, a little to the outside of the femoral artery, pierces the fascia immediately below the ligament, and becomes cutaneous, supplying the skin of the thigh at the middle part of its upper third. The division of the genito-crural into its terminal branches is subject to considerable variation, sometimes taking place either immediately after it has emerged from within the psoas, or within the psoas directly after its origin from the plexus. The crural division is at times also extremely small, the external cutaneous then having a more extensive distribution than ordinary.

The external cutaneous (external inguinal) is a branch from the second or from the second and third lumbar, or is occasionally derived from the outer part of the crural nerve. It passes from beneath the outer border of the psoas below its middle, runs across the iliacus towards the space between the two spinous processes of the ilium, lying behind the transversalis fascia. It then passes beneath Poupart's ligament, and divides into an interior and posterior branch. The posterior passes outwards and backwards over the fascia, covering the tensor vaginæ femoris, and supplies the integument at the upper, outer, and back part of the thigh. The extent of distribution of this branch is subject to variation, owing to the circumstance of a corresponding branch being occasionally supplied either by the great musculo-cutaneous, or by the genito-crural, when the trunk of the external cutaneous itself comes from the anterior crural. In such instances this branch is small and insignificant, if it exist at all. The anterior branch becoming cutaneous about the upper fifth of the thigh, soon divides into an external and internal, directed downwards, over the fascia covering the anterior and outer part of the rectus muscle. The external division terminates in the integument at the middle third of the outer part of the thigh; the internal at the lower third of the thigh, above and to the outside of the patella.

The *crural nerve* (femoral) is by far the largest branch of the lumbar plexus, and is placed in the substance of the psoas muscle between the external cutaneous, and the obturator, below the level of the former and above that of the latter, from which it diverges at an acute angle. It is formed by the union of the second with the outer branch of the third lumbar nerve, by part of the fourth, and generally by their communicating branch. It is destined to supply the integuments of the front of the thigh, and all the muscles at its anterior and outer portion.

Having emerged from the psoas muscle it is directed forwards and outwards between that muscle and the iliacus to Poupart's ligament, under which it passes, and entering the thigh becomes flattened and expanded, and divides into a series of divergent terminal branches, the trunk occasionally bifurcating before so doing.

The nerve in its course within the pelvis is situated behind the iliac division of the transversalis fascia, external to the iliac artery, and gives off a few branches to the psoas and iliacus. Outside the sheath of the femoral vein and artery it is separated from the latter by the intervention of the psoas muscle.

The terminal branches may be divided into *superficial and deep;* the first consisting of the *internal, and middle cutaneous, and branches to the femoral vessels and pectinæus:* the second of *branches* to the *quadriceps extensor cruris,* and the *cutaneous branch of the inner and*

anterior part of the knee and leg, viz. *the internal saphænus.*

The internal cutaneous nerve (internal musculo-cutaneous) directed along the inner border of the sartorius muscle, perforates the fascia at the lower third of the leg, occasionally perforating the sartorius before so doing. Having given off several cutaneous branches, which form a connexion with the cutaneous branch of the obturator in this situation, it continues its course towards the lower and inner part of the thigh, having previously communicated with a branch perforating the sartorius, and coming from the internal saphænus. From the thigh it passes along the inner edge of the patella, describing a curve, and sending some terminal filaments from its concavity upwards to unite with the middle cutaneous : others, from its convexity downwards, to communicate with the reflected branch of the saphænus itself, and also its accessory branch.

The accessory saphænus nerve (Cruveilhier) takes its origin from the internal cutaneous ; from the anterior crural in company with the latter ; or from the trunk of the saphænus itself. It soon divides into a *superficial internal branch*, which passes from within the sheath of the sartorius muscles over the femoral vessels, and adductor longus, and at the junction of about the upper with the middle third of the thigh meets with the internal saphæna vein, which it accompanies as far as the knee-joint, in which situation it communicates with the internal saphænus and cutaneous branch of the obturator. The *external branch*, situated behind the level of the superficial, is directed inwards to the femoral artery, runs along its outer part in close contact with it, and accompanies the vessel in Hunter's canal to its lower extremity. It then quits the artery, is directed in front of the tendon of the adductor magnus, to the upper part of the internal condyle of the femur, where it becomes cutaneous, anastomosing with the internal cutaneous above, with the reflected branch of the saphænus below, and sending cutaneous branches over the inner and middle part of the patella. This branch has been termed by Cruveilhier the *satellite nerve of the femoral* artery : and the superficial branch might with equal propriety be denominated the *satellite nerve of the saphæna vein.* The accessory saphænus is subject to considerable variation, both as to size and origin.

The middle cutaneous nerve perforates the fascia three or four inches below Poupart's ligament, crosses the sartorius muscle, and is directed over the inner part of the rectus to terminate in the cuticle over the front of the patella, anastomosing above with the external cutaneous nerve, and below with the internal cutaneous and accessory saphænus. It frequently divides about the middle of the thigh into two branches, which run parallel with each other. The internal and middle cutaneous nerves not unfrequently perforate the sartorius muscle before becoming cutaneous, the first at the middle, the second at its upper part. They are consequently described also as the *inferior perforating cutaneous*, and the *superior perforating cutaneous.*

The nerve to the femoral vessels is very delicate, and arises internal to the internal cutaneous, sometimes however coming off from the lumbar plexus. It is directed downwards and inwards to the femoral vessels, and divides into a series of filaments, one or two of which are directed through the cribriform fascia to the saphæna vein, along which they pass in a tortuous manner till lost by communicating with the internal branch of the accessory saphænus, about the middle of the thigh. The remainder pass, some behind and some in front of the femoral vessels, and terminate at the lower third of the thigh, by uniting with the external branch of the accessory saphænus.

The branches to the pectinæus are directed inwards behind the femoral vessels, and in their course to this muscle generally send a few filaments to the psoas.

The deep-seated muscular branches arise external to the internal saphænus nerve, and behind the superficial already described : and are from within outwards : Branches for the vastus internus and cruræus : branch for the rectus : and branches for the vastus externus, which are the deepest of all.

The branch for the vastus internus (short saphænus), taking its origin in close contact with the internal saphænus, from which it not unfrequently arises, is directed in company with, but external to it, along with the femoral artery. It separates a little below the middle of the thigh from the vessels, and is directed to the external aspect of the vastus internus, to enter it at its lower one third ; but before so doing gives off a *superficial articular branch*, which passes in front of the outer border of Hunter's canal ; in this situation occasionally communicating either with the cutaneous branch of the obturator, or the outer branch of the accessory saphænus ; crosses through the superficial muscular fibres of the vastus to its aponeurotic termination, which it perforates. It is then reflected forwards, upwards, and outwards, and terminates in two or three filaments, one of which passes behind the ligamentum patella, entering the anterior part of the knee-joint ; the others pass in front of the patella, to supply the periosteum and skin over it.

The nerve for the cruræus, shorter than that for the vastus internus, enters the upper and inner part of the muscle, extends as far as its lower part, and gives off filaments to the deep-seated portion of the muscle (the subcruræus) to the periosteum and upper part of the synovial capsule.

The branch for the rectus enters the upper part of its posterior aspect, and divides into a superior branch which passes transversely outwards, and a long vertical branch which passes along its inner side to the lower portion.

The branch for the vastus externus frequently arising in company with that for the rectus, is directed downwards and outwards between

that muscle and the cruræus, and, in company with the descending branches of the external circumflex artery, enters its inner aspect by two or three divisions, having previously given off a *superficial articular branch.* This filament, the analogue of the corresponding branch of the vastus internus, creeps beneath the superficial muscular fibres, and near the patella becomes cutaneous, some of the terminal filaments passing behind the outer part of the ligamentum patella, others over the patella, where they are lost in the skin and periosteum.

The saphænus nerve (σαφὴς, manifest), the most internal of the deep-seated branches, and arising behind and external to the middle cutaneous, is the largest branch of the crural. It passes downwards and outwards towards the femoral artery, and, about two or three inches below Poupart's ligament, enters its sheath. The nerve first lies outside and behind the artery; but a little before the vessel enters Hunter's canal it gets anterior to it. During the course of the artery downwards and outwards, to enter the ham, the nerve inclines forwards and inwards, and quits the canal, in company with the anastomotic artery, a little above the level at which the femoral vein and artery pass out. It now follows the course of the sartorius lying behind it, to the inner condyle, and one or two inches above the head of the tibia is placed between that muscle and the gracilis, and gives off, before continuing its course, the *cutaneous tibial* or *reflected branch.* This nerve first runs parallel for a short distance with the tendons of the two muscles, then sweeps downwards, forwards, and slightly upwards over the fascia covering them and their tendinous expansions, and across the spine of the tibia to the skin at the upper and outer part of the leg, about two or three inches below the head of the tibia, communicating above with the internal cutaneous.

The continuation of the nerve, or what may be termed the posterior trunk, inclines slightly backwards from between the tendon of the sartorius and gracilis, and on a level with the knee-joint is a little to the inner and back part of the tendon of the latter. Having received its connection with the cutaneous branch of the obturator, it passes in company with the saphæna vein into the region of the leg, inclining slightly forwards to the back part of the inner border of the tibia. Having supplied the integuments at the upper, inner, and anterior part of the leg, it inclines slightly backwards about its middle, sends filaments to communicate with the continuation of the cutaneous branch of the obturator at the posterior part of the leg. It then again inclines forwards, and terminates about three or four inches above the ankle in two branches. The anterior terminal, the smaller of the two, supplies the skin at the lower sixth of the inner and front part of the leg, and over the front of the ankle joint, a few of the branches entering the articulation. *The posterior* terminal, apparently the continuation of the trunk, supply the integuments over the inner malleolus, upper, inner, and back part of the foot.

The saphænus nerve not unfrequently, in its course in the thigh, in company with the femoral artery, gives off, at a variable height, usually however at the lower fourth of the leg, a small branch corresponding more or less with the distribution of the outer division of the accessory saphænus. The internal saphænus nerve first lies behind the corresponding vein; then in front of it to the middle third of the leg, when it again is placed behind it: an inch or two before it divides into its terminal branches, it is again anterior to it, the latter passing over in front, and the other behind.

The obturator nerve, derived from the third and fourth, and sometimes also from their internal intercommunicating branch, is much smaller than the anterior crural, and rounded. It perforates the inner border of the psoas, along which it is conducted to the pelvis, a little below the level of which it runs to between the external and internal iliac vessels. It then passes obliquely behind the external iliac vein, crossing it at a very acute angle, and reaches the obturator foramen in company with, and above, the obturator artery. It passes through this foramen into the thigh, and terminates by dividing into *superficial* and *deep divergent muscular* branches, situated behind the pectinæus and adductor longus. Soon after its origin a small nerve, the *accessory obturator*, is occasionally observed to proceed from the outer part of the trunk. It passes in company with the femoral vein, anterior and internal to it, beneath the femoral arch, over the horizontal ramus of the pubis, and external to the pectinæus. It is then directed a little inwards, and divides into several branches, some of which enter the joint through the anterior part of the capsular ligament; others supply the posterior surface of the pectinæus, and the remainder, as the continuation of the nerve, terminate by communicating either with the upper part of the trunk of the obdurator itself, or with the branch of the nerve destined for the adductor longus.

The obturator nerve, in passing through the subpubic canal, gives off two or three branches to the obturator externus muscle: one penetrating its upper edge, the others its anterior surface. Some *articular filaments* are also sent off in this direction, and accompany some of the branches of the inferior division of the obturator artery, beneath the transverse ligament to the hip-joint. The relation of these filaments as to size and numbers, however, is not constant, being in the inverse proportion to the size and number of branches given off from the accessory obturator, which is not unfrequently absent.

From the *superficial branch* is given off a long filament internally to the gracilis muscle, which runs for about two inches along the outer surface of the muscle before entering it, another to the posterior surface of the pec-

tinæus, which varies in its size according to whether this muscle be supplied by the accessory obturator or not: and a third to the adductor longus, which also enters its posterior surface.

The most important branch, however, is the *long cutaneous branch* which emerges from behind the lower border of the adductor longus muscle, passes in the fascia behind the internal saphæna vein as far as the knee joint, where it perforates the fascia, and becomes cutaneous at the anterior border of the tendon of the gracilis muscle. In this part of its course, a little below the upper third of the thigh, it communicates either with the internal branch of the *accessory saphænus*, or with a branch occasionally given off from the saphænus itself, and which accompanies the saphæna vein to the knee joint. It gives off cutaneous branches to the middle of the thigh, forming, with the above nerve, a more or less intricate plexus. Having perforated the fascia on a level with the knee joint, above it, or a little below it, it communicates with the trunk of the internal saphænus (being occasionally only in apposition with it), and internal cutaneous nerve. It terminates by being directed downwards and backwards to above the lower part of the popliteal region, and continues to give off cutaneous branches, till it is lost in the integument at the inner and back part of the leg to within two or three inches of the ankle: having previously sent filaments of communication to the continuation of the saphænus nerve.

The deep branch of the obturator runs generally behind the adductor brevis, and divides into two branches, one ramifying through the centre of that muscle: the other, *for the supply of the adductor magnus.* From the latter is given off a small articular nerve for the knee joint, which is directed downwards and outwards, towards the attachment of the adductor magnus to the linea aspera, perforates this attachment below the middle of the thigh, and is directed with the poplitæal artery into the ham, winding around the artery, and giving off an internal delicate branch, which enters the knee joint through the ligament of Winslow.

The Anterior Branches of the Sacral Nerves are six in number, and escape from the anterior sacral foramina, decreasing in size from above downwards, and presenting, consequently, characters reverse to what obtain in the corresponding branches of the lumbar nerves. They communicate with the sacral ganglia of the symphathetic, the filaments of communication being usually two between each nerve and the sympathetic.

The first nerve, smaller than the lumbo-sacral nerve, extends more obliquely downwards and outwards, and having passed from the first sacral foramen, unites with it at an acute angle, and communicates with the second nerve.

The second nerve, somewhat smaller than the first, passes more obliquely downwards and outwards from the second anterior sacral foramen, and, having communicated with the third, enters the sacral plexus, sometimes bifurcating previously.

The third nerve, about one-third the size of the second, comes from the third sacral foramen, and passes more horizontally outwards to the sacral plexus, having communicated with the second by a delicate filament sent in front of a portion of the pyriformis intervening between it and the second nerve.

The fourth nerve, considerably smaller than the third, passes from the fourth sacral foramen, communicates above and below with the third and fifth nerve, and terminates in three sets of filaments. One, usually in the form of a single trunk, is directed a little downwards and outwards, between the levator ani and the coccygæus muscle, gives branches to them, and finally becomes cutaneous. This filament in its course generally furnishes a small twig which perforates the great sacro-sciatic ligament, and terminates in the skin over the border of the coccyx. A second, as a single small trunk, passes to enter the sacral plexus. The third series anastomose freely with the hypogastric plexus, and then form of themselves a loose kind of interlacement, from which branches are given off to the rectum sides of the bladder, prostate, and vesiculæ seminales, and the vagina in the female. The levator ani generally receives one or two filaments, a distinct twig entering the middle, the other supplying the anterior part, after ramifying on the prostate.

The fifth passes from the fifth anterior sacral foramen, communicates above and below with the fourth and sixth, and sends a filament which perforates the eoccygæus muscle, supplies it, and terminates on the skin to the side of it.

The sixth (anterior branch of the coccygæal nerve) is extremely delicate, passing between the lower cornu of the sacrum, and the upper border of the coccyx, communicates within the bone with the descending branch of the fifth, and terminates by passing along the border of the coccyx in the substance of the saero-seiatic ligament to become cutaneous. Some filaments are given off from it which supply the coccygæus; others perforate the ligament, and are lost in the substance of the glutæus maximus.

The Sacral Plexus (sciatic) is formed by the lumbo-sacral nerve and the four upper anterior branches of the sacral nerves, principally, however, by the convergence of the three upper: the fourth sacral nerve sending merely a small filament of communication. The branches that contribute to its formation enter it at once, at a more or less acute angle, without any eomplex subdivision, as usually occurs in other plexuses. It has a well marked triangular figure, the apex being indicated by the line of convergence of the different trunks: the base by the trunks as they issue from the sacral foramina. It rests upon the pyriformis muscle, the internal iliac vessels separating it from the pelvic viscera, being however in immediate relation with a layer of pelvic fascia. Before terminating in the great sciatic nerve,

the plexus gives off a series of anterior and posterior branches. Of the former are observed, a nerve for the obturator internus, and the internal pudic: of the latter, the superior glutæal, inferior glutæal, nerves for the pyriformis, gemelli, and quadratus femoris.

The nerve for the obturator internus takes its origin from the upper and outer part of the plexus, being derived from the lumbo-sacral and first sacral. It passes behind the spine of the ischium, and the lesser sacro-sciatic ligament, reenters the pelvis at the lesser sciatic notch, and is distributed by three or four branches within the inner aspect of the muscle.

The internal pudic nerve, arising from the lower part of the plexus, and generally derived from the third and fourth nerves, passes behind the spine of the ischium, internal to the pudic artery, in company with the preceding, and then enters the ischio-rectal fossa, where it divides into a superior and inferior branch.

The superior branch (*the dorsal nerve of the penis*) ascends in company with the internal pudic artery, but above it, between the obturator internus and the levator ani, to pass between the two layers of the triangular ligament: perforating the anterior layer immediately under the pubic arch it gains the dorsum of the penis, in which situation it is placed in the fold of the suspensary ligament, and inclines inwards to the median line. Having given off one or more external branches, which run superficially as long and slender filaments along the upper and outer part of the penis, supply the corpora cavernosa and their integument, and are conducted as far as the prepuce, the nerve continues its forward direction. It passes to the side of the median line, sends numerous filaments to the skin; communicating branches to the nerve of the opposite side; and some to accompany the dorsal vein of the penis; and at the root of the glans penis, penetrates deeply between it and the corpus cavernosum, and terminates by sending numerous filaments throughout its substance.

The inferior branch (Perinæal nerve — superficial perinæal) perforates the obturator fascia at the inner and anterior part of the tuberosity of the ischium, and divides into two branches, an anterior and superior, having previously given off a posterior branch, named by Cruveilhier the *external perinæal*, which passes through the obturator fascia behind the tuberosity of the ischium. It runs in company with, but external to, the anterior branch, superficial to the crus of the penis, and terminates by supplying the lower and anterior part of the scrotum where it gives off filaments on the inside to unite with some from the anterior branch, on the outside to communicate with the long inferior pudendal branch of the lesser sciatic. The anterior branch passes in the interval between the accelerator urinæ and the erector penis, internal to the preceding, and inclines a little forwards and inwards, and ends in a series of long filaments, which communicate laterally with the external perinæal, and send branches to the middle of the lower and anterior part of the skin of the scrotum, some of them being conducted along the skin at the lower aspect of the penis as far as the prepuce. The superior branch soon divides into a series of muscular branches, after having passed above the transversalis perinæi muscle. Some are sent inwards to the external sphincter, levator ani, and accelerator urinæ: others to the erector penis; the termination of the nerve being represented by a small branch, which passes into the substance of the bulbous portion of the urethra.

The pudic nerve not unfrequently gives off *the inferior hæmorrhoidal* (anal), which passes along its inner side, is directed through the obturator fascia to the ischio-rectal space which it traverses to the side of the rectum, and at the upper border of the external sphincter divides into a series of filaments, the anterior of which communicate with the superior branch of the perinæal, and supply the front of the sphincter and the skin over it. The middle and posterior series supply the sides and back part of the sphincter. Some filaments are given off externally, which pass over the great trochanter, and communicate with the long inferior pudendal nerve. The skin about the anus is also freely supplied.

The inferior hæmorrhoidal, when not a branch of the pudic, is given off from the sacral plexus.

The superior glutæal nerve is derived either from the lumbo-sacral nerve only, or from two distinct roots, the one from it and the other from the back part of the first sacral nerve. The former source of origin usually obtains; and in the latter the root from the sacral nerve is not more than half as long as that from the lumbo-sacral. It passes out as a single trunk at the upper and fore part of the border of the sacro-sciatic notch, in front, and above the pyriformis, and divides into *a superior and inferior branch.*

The superior branch takes the course of the superficial trunk of the corresponding artery, courses along the convex border of the glutæus minimus, and supplies principally the upper and back part of the glutæus medius. The *inferior branch* is directed downwards, forwards, and outwards between the two glutæi, and, after a short course, divides into a superficial branch, supplying the upper and anterior part of the glutæus medius; and a deep branch running across the glutæus minimus, supplying it and the medius, and terminating near the great trochanter, by entering the substance of the tensor vaginæ femoris, at the lower, inner, and back part of its sheath.

The inferior glutæal nerve (lesser sciatic) arises from the back part of the sacral plexus by one or more roots. It emerges from the pelvis at the lower and anterior part of the great sacro-sciatic notch, either as a single, or as two, or three, trunks, below the pyriformis, and about a quarter of an inch behind and internal to the great sciatic. It is directed between the tuberosity of the ischium, and the great trochanter, but nearer the former,

over the back and inner part of the gemelli, and divides into *muscular and cutaneous branches. The muscular branches* are long and numerous, being destined to supply the glutæus maximus. One series are directed outwards, upwards, and forwards, and, entering its anterior surface, ramify through the substance of the muscle, as far as its upper and anterior part. The other series are directed downwards, backwards, and outwards, over the tuberosity of the ischium, and supply the lower and back part of the muscle.

The inferior glutæal having emerged from beneath the lower border of the glutæus maximus, divides into its two terminal branches, *perinæal cutaneous, and cutaneous branch to the thigh and upper part of the leg. The perinæal cutaneous nerve* is reflected upon the lower border of the glutæus maximus, and describes a curve, the concavity of which looks towards the sacrum. It soon divides into an external large branch, supplying the skin in the glutæal region, and an internal small branch (the long inferior pudendal of Sœmmering), which passes in a curved manner beneath the tuberosity of the ischium. It is then directed beneath the fascia of the upper and inner part of the thigh, running parallel to the ascending ramus of the ischium, and at or near the junction of the latter with the descending ramus of the pubis, perforates the fascia, and becomes cutaneous, supplying the skin in the perinæum; it anastomoses either with the superficial perinæal, or the external perinæal nerve, and sends terminal branches to supply the inner and outer portions of the scrotum, and the lower part of the skin of the penis.

The cutaneous branch to the back of the thigh and upper part of the leg. — The continuation of the trunk of the inferior glutæal is situated anterior and external to the above-named branches. It passes obliquely over the inner and back part of the biceps muscles, and, a little above the middle of the thigh, ordinarily divides into two branches. The small external branch passes downwards, forwards, and outwards to the upper part of the lower third of the thigh, in which situation it anastomoses with the external cutaneous nerve of the lumbar plexus. The large internal branch runs down a little to the inside of the median line of the thigh to the skin in the poplitæal region, where it divides into external terminal filaments, supplying the skin over the outer and back part of the tibia and fibula, and internal filaments, some of which go to the skin at the inner part of the poplitæal region, others very small, accompanying and surrounding the external saphæna vein, communicate below the middle of the leg with filaments given off from the external saphænus nerve.

The nerve for the pyriformis passes below the level of the superior glutæal nerve, from the middle of the back part of the plexus, generally taking its origin from the third sacral nerve. It is distributed to the anterior surface of the muscle.

The nerves for the gemelli and quadratus femoris pass from the plexus along the lower part of the pyriformis, close to the os innominatum, to the anterior surface of the muscles. That for the quadratus femoris gives off a few branches to the capsular ligament, one of which enters the articulation, and usually sends off the nerve which supplies the inferior gemellus. This nerve comes off frequently from the upper part of the great sciatic.

The great sciatic nerve (the sciatic, ischiatic, femoro-poplitæal), the largest nerve in the body, is formed by the convergence of a branch of the fourth lumbar, the lumbo-sacral, and the three or four upper sacral nerves; represents the termination of the sacral plexus, and is destined to supply the muscles at the back part of the thigh, and the muscles and integuments of the leg and foot. It escapes from the pelvis, from beneath the lower border of the pyriformis, as a flattened ribbon-shaped nerve, about half an inch broad, soon becomes rounded, and continuing its course from between the great trochanter and tuberosity of the ischium, descends with a slight inclination outwards to the back part of the thigh, a little to the outside of the median line, as far as, or somewhat above, the level of the upper angle of the poplitæal space, where it divides into terminal branches, the peronæal and posterior tibial. This division occasionally takes place within the pelvis, in which instances the outer division passes either between the lower fascicles of the pyriformis or above the muscle, the inner beneath the lower edge of the muscle. In some instances it takes place while the nerve is placed between the trochanter and tuberosity: in others, again, the two trunks are distinct as far as this situation, where they again unite, and subsequently divide in the poplitæal space. In the upper part of its course the nerve is rather deeply seated, being covered over by the glutæus maximus, and having behind and internal to it the branches of the inferior glutæal nerve. At the lower border of the tendon of the glutæus maximus it is crossed by the long head of the biceps, and in the remainder of its course is covered only by the fascia.

It is in relation in front with the two gemelli and obturator internus, the quadratus femoris and adductor magnus. Behind these muscles it passes successively from above downwards, is in close contact with the superior, and separated from the adductor magnus by a quantity of fat and cellular membrane. The branches given off from the sciatic nerve are muscular and articular. The muscular branches come away above the middle of the thigh, with the occasional exception of that for the short head of the biceps, which arises near the middle.

There are several *branches for the long head of the biceps*, some of which ascend to be distributed to the muscle at its origin; others descend for some distance, and enter its anterior surface.

The nerve for the semi-tendinous is a long delicate filament, which usually passes down

to the lower third of the thigh before it enters its surface.

The semi-membranosus generally receives *two or more branches:* and from the lower is not unfrequently derived a branch for the adductor magnus, which also receives a branch from the main trunk.

The articular nerve is usually given about the middle; but as this nerve, in the majority of instances, is derived from the peronæal, it will be described with that nerve.

The peronæal nerve (external poplitæal — external poplitæal-sciatic) is more superficial, and not much more than a third the size of the posterior tibial. It is directed downwards and outwards along the inner edge of the biceps muscle, behind the outer condyle of the femur, the outer head of the gastrocnemius, and the outer and back part of the head of the tibia, to below the head of the fibula, where it divides into four branches, *the anterior tibial,* and *musculo-cutaneous,* the former being larger than the latter.

The peronæal nerve, during this course, gives off *superficial cutaneous branches, and occasionally deep articular:* the former being represented by the *peronæal cutaneous and peronæal saphænus,* the latter *by the superior and inferior external articular.*

The peronæal cutaneous proceeds from the back part of the nerve, generally an inch or two after its commencement. Having passed superficially with the trunk as far as its termination, and having supplied the integuments in its course, it gives branches on the one hand to the integuments immediately on the outside of the external saphænus, and on the other over the upper part of the peronæus longus, the middle terminal filaments extending below the middle of the leg, and communicating with cutaneous branches from the external saphænus.

The peronæal saphænus (communicans fibulæ — communicating saphænus) usually taking its origin above and to the inside of the peronæal cutaneous, is directed downwards and inwards beneath the skin, and communicates with a corresponding branch from the posterior tibial to form the external saphænus. This communication is very variable as to situation, usually taking place below the middle of the leg, where it perforates the fascia, occasionally, however, in the lower part of the poplitæal space in front of the fascia. The nerve now and then runs quite distinct from its corresponding branch, which consequently in these instances entirely constitutes the external saphænus. It is either very small, terminating about the middle of the leg, or divides opposite the lower part of the tendo Achillis into branches which pass over the lower part of the peronæus longus to the skin of the external malleolus, where they communicate with small descending branches from the musculo-cutaneous; and into those which supply the skin at the lower and outer part of the heel, communicating in the interval between the heel and malleolus with branches from the external saphænus.

The deep articular branches are external and internal, the one arising above the other. They are thus described by Mr. Ellis*: — "*The superior external articular nerve,* arising either from the trunk of the sciatic or the external poplitæal in the case of a high division of the sciatic, is a long slender nerve, which descends deeply into the poplitæal space, under cover of the biceps muscle, nearly as low as to the outer condyle, then passes from the space beneath the tendon of the biceps, reaches the superior articular artery, which it accompanies to the front of the joint, and supplies the synovial membrane of the articulation.

The inferior external articular, more frequently a branch of the external poplitæal than of the sciatic, is also a long nerve close to the biceps, and has the same direction as the preceding; but it extends lower down, passing beneath the tendon of the biceps, and below the condyle of the femur, to the artery of the same name, and it divides on the outer side of the articulation into many branches that extend forwards, perforate the capsules, and supply the synovial membrane.

The anterior tibial nerve (interosseous nerve), rather larger than the musculo-cutaneous, passes from beneath the extensor communis digitorum, having previously perforated the deep surface of the peronæus longus, to the interosseous membrane, which it crosses obliquely downwards, forwards, and inwards; and a little below the middle of the leg is placed in front of the corresponding artery. It continues to accompany the vessel beneath the annular ligament, passing first to the inside of it, then to the outside, and again to its inside, while behind the annular ligament it divides into an internal and external terminal branch. The nerve in this course is placed first between the tibialis anticus and extensor communis digitorum; then between the former and the extensor proprius pollicis, and lastly between the extensor pollicis and the extensor communis digitorum. In its course from the leg to the ankle the anterior tibial gives off branches to the different muscles between which it passes; and also one or two delicate satellite filaments to the anterior tibial vessels.

The terminal branches are both rather deeply seated. The *internal deep branch,* the continuation of the trunk in reference to direction, but not to size, being smaller than the external, passes beneath the dorsal artery of the foot and the tendon of the extensor brevis destined for the great toe, gives filaments to supply the inner part of this muscle, and reaches the first interosseous space, sending a few twigs to the first interosseous muscle. At the anterior part of this space it communicates with the musculo-cutaneous, and terminates by dividing into two branches destined for the opposed sides of the first and second toes.

The external deep branch passes obliquely

* Ellis's Demonstrations of Anatomy, p. 675.

outwards beneath the exterior brevis, supplies this muscle, and gives off from its anterior part several delicate filaments, which running close to the tarsus reach the three outer interosseous spaces, and expand in the substance of the interosseous muscles.

The musculo-cutaneous nerve (the external peronæal), commencing its course below and behind the anterior tibial, and running more superficial and external than it, is directed, first obliquely then vertically downwards in the substance of the peronæus longus; it is then situated behind the fascia, and at a variable distance from the ankle, generally at the lower third, perforates the fascia, between the extensor communis, and peronæus tertius. Subcutaneous in the remainder of its extent, it follows the course of the extensor communis, and after running for a greater or less distance parallel to it, divides into an internal and external branch which diverge considerably from each other. This bifurcation is subject to variation, taking place sometimes while the nerve is situated behind the fascia, at others over or very near the annular ligament, and occasionally the two divisions reunite over the annular ligament, and form an irregular oval space between them. While passing deeply between the muscles of the leg this nerve sends two filaments to the peronæus longus, the inferior of which, given off about the upper fourth of the leg, can be traced running in the subtance of the muscle, to within two or three inches of the ankle. The upper part of the peronæus brevis also receives a small branch. Shortly after perforating the fascia, the musculo-cutaneous sends off its *malleolar branches* directed downwards and outwards to the skin over the outer ankle, and anastomosing with cutaneous branches either from the external saphænus, or the termination of the peronæal cutaneous.

The internal terminal branch, passing over the annular ligament giving a few branches to it, and some to communicate with the internal saphænus and anterior tibial, is directed along the inner border of the foot to the inside of the great toe as far as its extremity. *The external branch*, having passed over the annular ligament, divides into three branches which are directed along the three outer interosseous spaces, and near their anterior extremities, each branch again subdivides into two filaments supplying the opposed sides of the four outer toes, the most external filament anastomosing with the external saphænus. Both terminal branches, in their course from the annular ligament to the toes, send off numerous filaments to the skin on the dorsum of the foot. Such is the usual distribution of the musculo-cutaneous nerve; but frequently the outer branch does not supply the inner side of the little toe, and occasionally gives filaments only to the opposed sides of the second and third toes. In these instances an extension of the external saphænus nerves compensates for the deficiency.

The tibial nerve (tibial-sciatic, internal poplitæal) much larger than the peronæal or external poplitæal, is in a direct line with the sciatic nerve. It passes through the centre of the poplitæal space, rather nearer the semimembranous than the biceps, then between the two heads of the gastrocnemius to the lower border of the poplitæus. It perforates the tendinous arch of the solæus, reaches the front of that muscle, and passes down the leg between it on the one hand and the deep-seated muscles on the other. At the lower third of the leg it runs from beneath the inner border of the solæus, and continues its terminal superficial course, anterior and internal to the tendo Achillis, as far as the lower extremity of the tibia, and, on a level with the base of the external malleolus, divides into the internal and external plantar. In the upper part of the poplitæal span, the tibial nerve is superficial and external to the poplitæal vessels in the middle immediately behind, and at the lower part is placed internal to them. This last relation the nerve holds as far as the lower third of the leg, when it crosses the posterior tibial artery again to its outer side. It continues very gradually to separate from the vessel; so that in the interval between the heel and malleolus the nerve is a quarter of an inch nearer the os calcis than the vessel. The branches given off from the tibial are *muscular, articular, and cutaneous.*

The majority of the muscular branches arise from the posterior part of the trunk, and we observe, first, two branches for the two heads of the gastrocnemius entering their anterior surface. The inner branch arises frequently from a trunk common to it and the tibial saphænus; the outer, from a trunk common to it and a large branch for the solæus, which enters, usually, the posterior surface of that muscle. When the outer branch is small, one or two others are given off lower down, to enter its anterior aspect. *The small branch for the plantaris* is derived, in the majority of instances, from the trunk of the tibial; but sometimes from the inferior internal articular nerve.

The nerve for the poplitæus, given off opposite the knee-joint, is directed forwards to the poplitæal vessels, descends external to them, and terminates at the lower border of the muscle by entering its substance.

The nerve to the tibialis posticus comes off from the above, descends along the back of the muscle, gives numerous filaments to it, and terminates by entering below the middle.

The nerve for the flexor communis digitorum and the longus pollicis take their origin together somewhat below the preceding; that for the latter muscle being the larger, and descending to within a short distance of the ankle joint, in company with the fibular artery. The articular branches are three in number, and correspond with the internal and anterior articular branches of the poplitæal artery.

" *The superior internal articular*, very small, arises above the articulation, descends on the outer side of the poplitæal vessels, passes beneath them, and runs with its artery to the

front of the femur and inner part of the articulation; this is the least constant of the branches. *The inferior internal articular*, the largest of the nerves to the joint, arises rather above the articulation, descends to it, lying external to the vessels, is then directed inwards, beneath the poplitæal vessels, and meets with the artery of the same name; it now lies on the poplitæus, covered by the fascia, passes beneath the internal lateral ligament, winds round the head of the tibia, perforates the capsule, and supplies the synovial membrane. This branch gives, occasionally, some filaments to the posterior part of the articulation. The last articular branch is the *posterior* or *azygos*, which is given off opposite the joint, or from the inferior internal nerve: it perforates the posterior ligament, and is distributed to the articulation."* We have observed this inferior articular nerve give off, occasionally, muscular filaments to the plantaris, and upper part of the poplitæus.

The cutaneous branch is named the *tibial saphænus* (external saphænus — communicating saphænus — communicans tibiæ), and takes its origin from the back part of the trunk external to the muscular branches. It inclines a little to the outside of the middle of the poplitæal space, under the fascia, but superficial to the gastrocnemius, along the posterior surface of which it passes till it perforates the fascia at a variable distance from the ankle, and receives the corresponding branch from the peronæal saphænus. It is then directed, under the name of the *external saphænus*, along the outer part of the tendo Achillis to the outer and back part of the external ankle, where it divides into its terminal branches. In the first part of its course it lies to the inside of the external saphæna vein. Near the lower angle of the poplitæal span it passes in front of the vein to get to its outside, continues external to it as far as about an inch above the outer ankle, and again passes in front of it to its inside.

The tibial saphænus gives off no branch till it becomes external saphænus, and internal and external cutaneous branches arise from it. The internal supply the outer and back part of the leg: and a *superior and inferior calcaneal branch* are generally observed. The superior is directed over the tendo Achillis, supplies the skin at the inner and back part of the heel, and communicates with filaments from the external plantar: the inferior passes along the outer border of the tendo Achillis to the skin at the outer and lower part of the heel. The outer cutaneous run downwards and forwards over the tendon of the peronæus longus, as far as the malleolus externus, communicating above with descending filaments of the peronæal cutaneous; and below with the malleolar filaments of the musculo cutaneous. Independent of these, cutaneous filaments and a few delicate nerves are given off, which accompany the saphæna vein.

The terminal branches are composed of a series of cutaneous branches to the back part of the ankle, heel, and back part of the outer edge of the foot, and a long nerve, the continuation of the trunk directed along the outer edge of the foot to supply the outer margin of the little toe, communicating previously with the musculo-cutaneous.

The termination of the tibial saphænus nerve is subject to considerable variation, both as to size and distribution. It occasionally forms no connection with the peronæal saphænus, and then is very large. When united with the peronæal saphænus, so as to form the external saphænus, its terminal branch not unfrequently divides into two; the one division for the opposed edges of the fourth and fifth toe; the other for the outer edge of the latter. We have observed the saphænus nerve supplying also the opposed edges of the third and fourth toes, whilst the musculo-cutaneous in this instance supplied merely the inner edge of the great toe and the opposed margins of the second and third toes.

The tibial nerve, before dividing into the internal and external plantar, gives off, a little above the ankle, an *internal calcaneal branch*, which in a high division of the nerve comes away from the external plantar. Having supplied the skin at the inner aspect of the heel, it winds beneath the inferior surface of the os calcis, and communicates with the calcaneous branch of the external saphænus.

The internal plantar nerve, larger than the external and analogous to the median nerve in the hand, passes behind the internal malleolus superficial to and distinct from the tendons of the tibialis posticus, and in front of the posterior tibial vessels. It then runs above the abductor pollicis, and is directed in the intermuscular septum, between it and the flexor brevis digitorum. Having perforated this, it appears between the two muscles, and divides into internal and external branch es

The internal branch is smaller than the external, passes from without inwards over the tendon of the long flexor of the toe to the inner side of the metatarsal bone, gives filaments to the abductor pollicis, flexor brevis, and the skin, and terminates at the inner side of the toe, supplying in its course filaments to the articulations, and when it reaches the last phalanx, a small cutaneous branch to the dorsum.

The external branch divides after a course of about an inch or two. The internal division, as it is directed along the first interosseous space, gives off in its course filaments to the first interosseous and lumbricalis, and at the anterior part of this space divides into two twigs for the opposed sides of the great and second toe. The external division, after a very short course, divides into two branches: the *internal* crosses obliquely the second interosseous space, gives filaments to the second lumbricalis, and bifurcates at its anterior extremity for the supply of the opposed sides of the second and third toes: the *external* crosses obliquely to the third interosseous space, and like the preceding divides at its anterior extremity into two twigs for the

* Ellis's Demonstrations of Anatomy, p. 676.

opposed sides of the third and ourth toes, having previously communicated with the external plantar.

These different divisions of the internal plantar nerve give off, in their course, filaments to those portions of the cuticle with which they are in relation; and also small twigs for the metatarso-phalangeal and phalangeal articulations, and muscular branches to the flexor digitorum brevis, over the tendons of which the different divisions of the external portion of the nerve are obliquely and superficially directed.

The external plantar nerve, smaller than the internal, is directed forwards and outwards between the musculus accessorius and flexor digitorum brevis, giving filaments to either, and, having reached the inner border of the abductor minimi digiti, which muscle it supplies, divides into a deep and superficial branch.

The deep branch passes from between the first and second layer of muscles to place itself between the latter and the third, passing in company with the exterual plantar artery. It describes a curve, the concavity of which looks towards the heel and inner malleolus. Filaments are sent off for the two outer lumbricales, for the transversalis pedis, the adductor pollicis, the interossei, and the tarsal and metatarsal articulations.

The superficial branch passes obliquely forwards and outwards between the flexor brevis digitorum and abductor minimi digiti, to both of which it gives filaments, and soon divides into an external and internal branch.

The external branch reaches the outer border of the foot, and terminates at the extremity of the outer aspect of the little toe; giving filaments to the flexor brevis minimi digiti and the articulations. The internal, larger, communicates with the most external division of the internal plantar, and bifurcates at the extremity of the fourth interosseous space, for the supply of the contiguous sides of the fourth and fifth toes. The divisions of the superficial branch of the external plantar nerve, like those of the internal, supply the portions of the integument with which they are in relation, as also the articulations over which they pass.

The internal and external plantar nerves are, in reference to size, directly the reverse of the corresponding arteries: the former giving off seven filaments for the supply of the three inner toes, and half of the fourth; and being analogous in its distribution to the median in the hand: the latter giving off only three filaments for the fifth and half of the fourth toe, and corresponding with the distribution of the termination of the ulnar nerve.

(*Nathaniel Ward.*)

SPLEEN. (*Lien seu Splen*, Lat.; Σπλήν, Gr.; *die Milz*, Germ.; *la Rate*, Fr.) Normal anatomy. The spleen is a single so-called "vascular gland," which is attached to the cardiac extremity of the stomach, and appears to possess some intimate connection with the renovation of the blood.

Situation and form. — The spleen has a roundish elongated form, or almost the shape of half an egg, and lies in the left hypochondriac region. We recognise on it two surfaces, two borders, and two extremities. The *outer surface* (*superficies externa seu convexa*) is completely free and smooth, and often exhibits a more or less deep, long, and oblique incision: it looks outwards, upwards, and backwards; and is in contact with the left costal portion of the diaphragm, corresponding to the tenth and eleventh ribs. The *inner surface* (*superficies interna seu concava*) is directed inwards and forwards; is for the most part slightly concave, and presents, in a prolonged elevation which occupies its middle, a vertical furrow, the fissure for the vessels, or *hilus lienalis*, which contains many holes and depressions, through which pass the nerves and vessels to and from the spleen. This fissure separates the concave surface into an anterior and larger, and a posterior and smaller portion; and it is connected by the broad, but short gastro-splenic omentum (*ligamentum gastro-lienale*), with the fundus of the stomach, to which the remainder of the concave surface is opposed. The *upper extremity* or head of the spleen (*caput lienis*), is the thicker and more obtuse of the two; it occupies the elevated hinder part of the eighth rib, and is connected by a suspensory ligament (*ligamentum phrenico-lienale seu suspensiorum*) with the diaphragm. The *lower extremity* or *cauda lienis*, is thinner and more pointed, and is directed downwards and forwards. The *anterior border* (*margo anterior*) is the thinner and sharper, and is free. The *posterior border* (*margo obtusus*) is thick and rounded, and is in contact with the lumbar portion of the diaphragm, and the anterior surface of the left suprarenal capsule. The spleen is thus least moveable, where it is limited by the diaphragm; but much more so at the site of its attachment to the stomach. But its situation changes with the variable positions of the diaphragm and stomach: thus, on the one hand, it descends and rises in the states of in- and expiration respectively; and, on the other hand, becomes more superficial or deeper, according as the stomach is empty or full.

Varieties of the spleen. — It is not uncommon to find the anterior border of the spleen, presenting one or more separate deep fissures. Also supplementary spleens (*lienculi, seu lienes succenturiati*) are now and then observed: according to Rosenmüller and Giesker, more frequently in the Southern than in the Northern Germans. These are situated in the gastrosplenic ligament, and rarely in the great omentum (Morgagni, Huschke); they are red, of the ordinary splenic structure, and of a size which varies from a linseed to a walnut. They are generally one or two in number, less frequently four or seven, and in a misdeveloped fœtus have even amounted to twenty-three.

The *size and weight* of the spleen experience great variation, not only in different individuals, but even in one and the same person;

of this more will be said hereafter. On an average, its length is from 4 to $5\frac{1}{2}$ inches * ; its thickness from 1 to $1\frac{1}{2}$ inches ; and its breadth, from the anterior to the posterior border, 3 to 4 inches. According to Krause, its cubic contents range between $9\frac{3}{4}$ and 15 inches, with an average of 12. Its absolute weight varies from 6 to 15 oz., according to Soemmering ; from $7\frac{1}{2}$ to $10\frac{1}{2}$, according to Krause; and it has a medium of about 8 oz. According to J. Reid †, between the twentieth and sixtieth years, it ranges from 6 to 10 oz. in the male, and from 3 oz. $13\frac{1}{2}$ dr. to 9 oz. 10 dr. in the female. Krause also states, that its specific gravity varies from 1.0579 to 1.0625, with an average of 1.0606.

The *consistence* of the spleen is not very great : its parenchyma is soft and doughy, readily yielding to the pressure of the finger. It is not unfrequently torn by mechanical injury during life ; indeed, more easily than any other glandular organ, especially if it be over-distended with blood at the time; but, under the opposite circumstances, it is much less disposed to give way. The colour of the spleen is bluish red, during life greyish violet, and the parenchyma is of a dark dusky red.

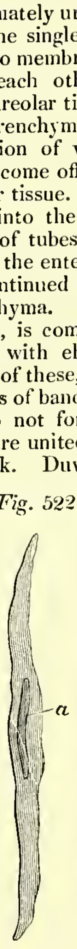
Structure. — In the spleen we first distinguish the *coverings* or *involucra*, and the *parenchyma* or proper spleen-substance. The first consists of the serous and the fibrous membrane. The latter is composed of a framework of reticulated fibres firmly connected together, constituting the so-called trabecular tissue (*trabeculæ lienis*) ; and, beside this, of the red spleen-substance, the splenic corpuscles, and vessels and nerves, together with sheaths which arise from the fibrous coat.

1. The *serous membrane* (*tunica serosa*) is a part of the peritoneum. It accurately covers the outer surface of the spleen as a smooth membrane, with the exception of its hilus only, where it takes the form of two folds which convey the vessels of the organ, constituting the gastro-splenic ligament, and passing off to the stomach, where they become continuous with its serous covering. When the ligament uniting the spleen to the diaphragm exists, the membrane is similarly continuous with the peritoneum covering this muscle. The serous membrane is a thin, moderately strong, whitish membrane, which is intimately connected with the fibrous coat ; although in particular places, and especially after previous maceration, the two may be separated from each other. In respect of its microscopical structure, it scarcely differs at all from other parts of the visceral layer of the peritoneum; thus it consists of an outer and single layer of polygonal pavement epithelium, and of an inner layer of white fibrous tissue, in which meshes of fine fibre of yellow tissue are present in no very considerable quantity.

In mammalia, *e. g.* in the sheep, ox, &c., as was remarked by Malpighi, the serous membrane is easily separated entire. But in man this is not the case, and hence Haller and others have supposed that only one membrane is present. But microscopical research proves the opinion to be erroneous ; and pathological anatomy confirms this statement, by showing that the outer part of the coat of the spleen shares in the diseases of the peritoneum. In animals numerous vessels are seen in the serous membrane, and a very dense network of stronger and thicker fibres of yellow tissue is present.

2. The *fibrous coat* (*tunica fibrosa, albuginea, sive propria*) is in man a moderately delicate semi-transparent, but firm, membrane, which encloses the parenchyma of the spleen on every side, so as to include it in a kind of sac. Its outer surface is even, and in man is intimately united with the serous covering, with the single exception of the hilus, where the two membranes diverge, and are separated from each other by vessels, nerves, and a loose areolar tissue. The inner surface bounds the parenchyma of the organ, and, with the exception of very numerous solid processes which come off from it, is limited by the trabecular tissue. At the hilus of the spleen it sinks into the interior of the organ in the shape of tubes (*vaginæ vasorum*), which ensheath the entering and emerging vessels, and are continued on these throughout the whole parenchyma. The fibrous coat, in the human subject, is composed of white fibrous tissue, mixed with elastic or yellow fibres. The former of these, as in other fibrous membranes, consists of bands, which take a parallel course, but do not form distinct bundles ; and the latter are united in a very dense and irregular network. Duvernoy and Stukely have described muscular fibres in this tunic; but, according to my researches, they certainly are not present in the human subject, although I have found them existing in some of the mammalia, and most visibly in the dog and pig. They are unstriped muscles, the elements of which, the elongated cells or "fibre cells" (*fig.* 522.) which I have described *, are deposited in considerable quantity amongst the elastic network and white fibrous tissue previously mentioned. In addition to these two animals I have also found the muscular structure in the cat, the ass, and the Dicotyles

Fig. 522.



Muscular fibre-cell from the tunica propria of the spleen of the Dog, magnified 350 diameters. *a*, nucleus of the same.

* In this and the following measurements the German inch and line have been retained.

† London and Edinburgh Monthly Journal, April, 1843.

* Zeitschrift für wissenschaftliche Zoologie, von v. Siebold und Kölliker, Leipzig, bei Engelmann, Jahrgang, 1848, Heft 1.

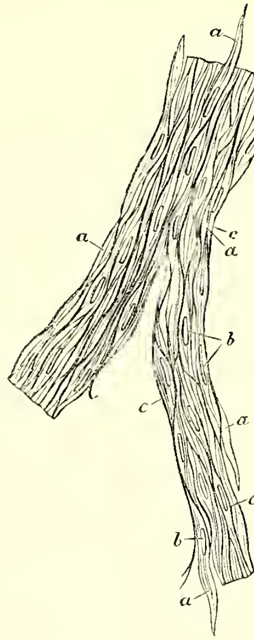
torquatus, while it was absent in the rabbit, horse, ox, hedgehog, guineapig, and bat. The elastic fibres of this tunic are for the most part much stronger than in man.

Their peculiar vessels and nerves I have never witnessed.

3. The *trabecular tissue*, (*trabeculæ lienis*, *balks*, or *joists* of the spleen), consists of white, shining, flat or cylindrical fibres, which arise in great numbers from the inner surface of the fibrous coat; and, in smaller quantity, from the exterior surface of the sheaths of the vessels. These are so connected with similar fibres in the interior of the spleen as to constitute a network which extends throughout the whole organ. Between the fibres of this net exist a great number of spaces which are connected with each other, and are occupied by the red spleen-substance and splenic corpuscles; and which, although very irregular in respect of their form, and, as regards their size, of the most variable dimensions, have yet a considerable resemblance to each other. The older anatomists regarded these spaces as regular and uniform cavities provided with a special membrane. But this last structure nowhere exists, as may be verified in a spleen in which, after short maceration, the pulp has been removed from these spaces by washing. Such a preparation will also afford the best means of studying the mode of connection of the fibres, and in this manner it may be seen that, although they are of very different diameters, yet the finer fibres are not everywhere given off from the thicker ones. This is especially shown by the fact, that fibres of the most different diameters are intimately connected together at all points. Where four, five, or more of these joists meet, there generally occurs a knot of a flattened cylindrical form, which is not unlike that of a nerve-ganglion. Such knots are more frequently found towards the outer surface of the organ, since the cross-beams are more numerous here than in the interior. In this latter part, namely in the neighbourhood of the great vessels, the numerous ramifications of these tubes themselves serve as points of support to the pulp, and consequently render the joists less necessary.

The structure of the trabecular tissue of the human spleen completely corresponds with that of the fibrous tunic, since it consists of white fibrous tissue and the yellow fibres. The former of these two structures exhibits parallel fibrillæ, which run without exception in the direction of the long axis of the partition or joist, and rarely unite into individual bundles. The latter consists of somewhat finer and stronger yellow fibres, which anastomose with each other; their maximum diameter is 1,1000th of a line: the greater number of them lie between the bundles of white fibrous tissue, and are easily recognised by their irregular course and manifold curves. Many anatomists, with Malpighi, had spoken of muscular fibres in the partitions of the spleen, although none had succeeded in demonstrating them, either with the scalpel or microscope, or chemically. But in 1846 I discovered them with the aid of the microscope, in the spleen of the pig.* Here they exist both in the finest and largest of the partitions, but they are not isolated, being connected with the finer reticulations of the yellow fibres (*fig.* 523.). In the larger partitions which are

Fig. 523.



A trabecula from the Spleen of the Pig, magnified 350 *diameters, and treated with acetic acid.*

a, muscular fibre-cells with a projecting extremity or not isolated; *b*, nuclei of the same; *c*, elastic fibres.

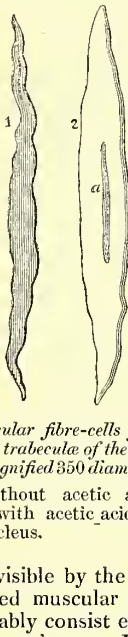
visible to the naked eye, the muscular and elastic fibres are present in pretty nearly equal quantities, consequently these parts are to be regarded as alike elastic and contractile. But in the smallest and microscopic cross-beams the muscular fibres predominate, and often they appear to be even unmixed with elastic fibres. In these parts the quantity of white fibrous tissue is still smaller than that of the yellow; indeed, in this animal it is but very sparingly present in the larger partitions. The direction of the fibres above-named is always longitudinal or parallel to the long axis of the joist, never transverse. In similar extent and quantity, and with a like connection to the elastic tissue, I have found muscular fibre in the dog, the ass, the cat, the Dicotyles torquatus, the sheep, rabbit, horse, hedgehog, guineapig, and bat. In the ox, on the contrary, it exists only in the finer and microscopic partitions, where it is present in very considerable quantity and in remarkable distinctness. The remainder of the trabecular tissue consists only of yellow fibre in union

* Mittheilungen der naturforschenden Gesell schaft in Zurich, 1847, S. 120.

with some white fibrous tissue. As to the lower vertebrata, I have examined a great number of them with respect to this muscular structure, and have found that the smallness of the spleen in many of them offers a great obstacle to observation ; yet I believe I have verified that the spleens of the pigeon, sparrow, blindworm, tench (*tinca chrysitis*), and trout, contain muscular fibres. So, also, my friend Professor Ecker, of Basle, has orally communicated to me that he has found very distinct muscular fibre in the spleens of the ray and shark.

All these muscles are, like those of the fibrous coat, unstriped ; their elements consist of elongated shortish fibres, each possessing a long nucleus. (*Fig.* 523. *a*, *Fig.* 524.) In the thicker partitions there are what I call "muscular fibre-cells," either stiff, pale, flat, from 4 to 6.1000ths of a line broad, and 2 to 3.100ths long, or more cylindrical, darker, spindle-shaped, and undulating, varying from 2 to 5.100ths of a line in length, and 3 to 4.1000ths in breadth. In both cases they have long, neat, small, staff-shaped, nuclei. In the finer partitions, on the contrary, appear many shorter and more spindle-shaped fibre-cells ; their nuclei are elliptical or even spherical, and they often project laterally from the fibres, so as sometimes to render these muscular elements scarcely distinguishable from the spindle-shaped epithelial cells of the splenic arteries.

Fig. 524.



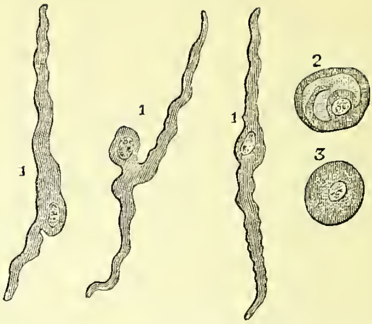
Muscular fibre-cells from the trabeculæ of the Pig, magnified 350 *diameters.*

1, without acetic acid; 2, with acetic acid; *a*, nucleus.

The muscular elements just described are seen in the best and plainest manner in the pig and dog ; but they are also readily verified in the horse, ox, ass, sheep, and cat, in all of which they may frequently be isolated. In the other mammals previously named, and in the rest of the vertebrata, they are less easily recognised, and are scarcely susceptible of isolation ; but they can always be partially uncovered, and in any case may be demonstrated by the application of acetic acid, which displays their characteristic nuclei.

As regards the human subject, I find that in the partitions which are visible by the naked eye, no trace of unstriped muscular fibre is present; and they probably consist entirely of yellow and white fibrous tissue. In the finer partitions, on the contrary, elements occur to which one may perchance ascribe a muscular character. They are the same short fibres of a peculiar kind (*fig.* 525. 1.), which Günsburg* has

Fig. 525.



Peculiar structures from the human spleen, magnified 350 *diameters.*

1, spindle-shaped fibres with a nucleus; 2, a cell, which contains such a fibre; 3, a similar cell, without a fibre.

erroneously regarded as epithelial cells of the splenic veins ; otherwise they have hitherto remained altogether unnoticed. They are characterised by their roundish or elongated oval nucleus, which is laterally disposed, and often occupies a pedunculated process ; by their homogeneous texture ; by their easy undulatory or serpentine outline ; and, finally, by their size, which offers a breadth of 15 to 25-1000ths, and a length of 2 to 3-100ths of a line. The round nuclei of these fibre-cells, even at first sight, somewhat militate against their muscular import ; but it must be recollected, that in the mammals named it has been previously stated that the muscular fibre-cells, which occur in the smallest partitions, deviate considerably from the characteristic fibres, and greatly resemble the structures now described in men. On this account, and from the further fact, that the above mentioned human fibre-cells, in moderately fresh spleens, seem to occupy the smallest partitions, just as the muscular fibres in animals ; while in later periods after death, or in decomposed spleens, they can only be found isolated, with the parenchyma cells, in the red pulp of the spleen, I formerly considered it not too hazardous to regard them as muscular fibre-cells. But more recently I have made some observations which have again thrown me into complete uncertainty in respect of the import of these questionable structures. Thus I believe myself to have verified, that these fibres occur in the human subject rolled together in a kind of spherical cell (*fig.* 525. 2,) of 5 to 7-1000ths of a line in diameter ; and that, on tearing up this structure they become free, and extend themselves. But, since this fact in no way harmonizes with the nature of muscular fibre-cells, and is besides altogether obscure and incomprehensible to me, I hesitate to express at once an opinion concerning the above-mentioned structures in the human spleen, but am desirous of calling the attention of inquirers to this peculiar arrangement, which, on account of its constancy and frequency, is very interesting.

* Pathologische Gewebelehre, Band. i. S. 81.

4. The *splenic corpuscles* or *Malpighian corpuscles of the spleen* (*vesiculæ seu glandulæ lienis, s. corpuscula Malpighii*) are whitish spherical corpuscles, which are imbedded in the red spleen substance of certain animals, and are connected with the smallest arteries. In the dead bodies of men, in the state in which they are generally subjected to examination in hospitals, these corpuscles are very seldom seen. On this account, some of the earlier observers, as Rudolphi, Heusinger, Andral, and others, and more recently Gluge * and Oesterlen †, have regarded them as not constant structures, or even as products of disease; or have considered them as J. Muller formerly did ‡, to be altogether distinct from the splenic corpuscles of the Ruminantia. But this view is erroneous, and since Giesker §, Krause ‖, and Bischoff ¶, who described the splenic corpuscles of the human subject, and showed their correspondence with those of the mammalia; and since the revocation by Müller of his earlier opinion **, all observers are tolerably agreed, that although the corpuscles in question are often deficient in the human subject, yet they are not the less to be regarded as normal structures, which are invariably present in the healthy subject.

The frequent deficiency of the splenic corpuscles is explained by many circumstances. Most of the observations of them concern human individuals, in whom a long abstinence from food has preceded death. In such cases, as Henle has well remarked ††, the apparent absence of the corpuscles is easily explicable, since their size is notoriously regulated by the quantity of ingesta. So, also, great number of the human spleens which come under our notice are diseased; either softened, distended with blood, and soaked through with extravasations, or enlarged, hardened, atrophied, or already half decomposed and putrified. Finally, the human spleen corpuscles are very delicate, and easily destroyed. As to the frequency of their occurrence in diseased subjects, we are supplied with accurate data by v. Hessling, who has given the results of 960 dissections. Of the whole number just mentioned, Malpighian corpuscles were only present in 116, or in about every eighth individual. He also adds the following numerical statement respecting the different ages of life. In the first and second year of life the corpuscles were present in every second subject; from the second to the tenth year, in every third subject; from the tenth to the fortieth year, in every sixteenth; from the fortieth year to old age, in every thirty-second. These numbers are in general correct, and are readily explicable when we recollect that diseases of the spleen are more numerous as age advances. But the results of my own observations coincide with those of Oesterlen, in representing the number of cases in which corpuscles are detected as greater than that above mentioned. This difference may be ascribed to the difficulties which often prevent the recognition of the dwindled spleen corpuscles; thus in many cases where the first view has afforded no signs of their presence, the application of soda, or the washing of the pulp, has brought them into view.

On the other hand, it is absolutely certain that, in many spleens, they disappear without leaving any traces, and cannot be made visible by any method of treatment. In the bodies of healthy individuals which are examined while fresh, they may always be detected; at least, there are very numerous observations extant in which they have been found after accidental deaths, executions, suicides, &c.; and to these cases I myself am enabled to add two. So, also, I have found them in a great majority of the bodies of children which I have examined; and here they are both very distinct and numerous, so as not to offer any visible difference, in these respects, from those of the Ruminantia.

The size of the Malpighian corpuscles experiences many variations both in men and animals, even apart from the effects of disease: they measure from one-tenth to one-third of a line; on an average, about one-sixth. Their size has hitherto been somewhat too highly estimated; and chiefly on this account, that sufficient preliminary care has not been taken to isolate them from the surrounding parts: when this is done it will be found, that they are not so large as appears from viewing them on a section of the spleen; and that, in many cases, they measure less than the given bulk. The fluctuations in their size depend not merely upon the differences of individuals, but obtain in one and the same animal: in this latter case, they appear mainly to be regulated by the condition of the chylopoietic viscera; although accurate data, as to these points in the human subject, are altogether deficient.

It is also possible, as Oesterlen has supposed, that these corpuscles experience a certain course of development; and that, in many cases, the very small corpuscles are very young and undeveloped ones: but, hitherto, I have not been able to observe facts importing the certain existence of a continual development of the Malpighian corpuscles in the adult animal; nevertheless, I cannot avoid mentioning that, like Oesterlen, I have seen in the spleens of animals little heaps (from 2 to 4-100ths line in size) of cells, which have no distinct cell walls, and which, possibly, have some relation to the formation of the splenic corpuscles. It seems quite certain that the spleen corpuscles are not developed from separate cells of the spleen pulp; although this view has lately been brought forward in a singular manner by Heinrich.*

* Häser's Archiv. für die gesammte Medicin, 1841, SS. 83. 88.

† Beitrage zur Physiologie des gesunden und kranken Organismus, Jena, 1843, S. 48.

‡ Müller's Archiv, 1824, S. 80.

§ Splenologie, S. 159.

‖ Anatomie, Band. i. S. 520.

¶ Müller's Archiv, 1838, S. 500.

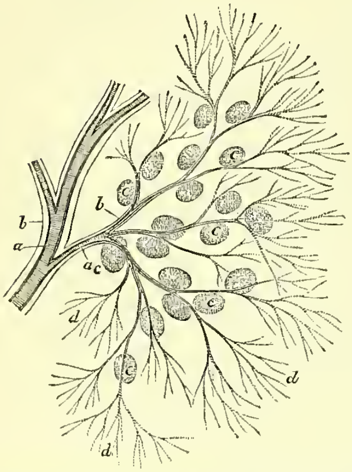
** Physiologie, Aufl. 4. Band. i. S. 466.

†† Algemeine Anatomie, S. 1000.

* Die Krankheiten der Milz, 1847, S. 15.

The *Malpighian corpuscles* are imbedded in the red spleen substance, and, with the exception of one point, where they are attached to arterial twigs, they are everywhere surrounded by this substance. They are con-

Fig. 526.

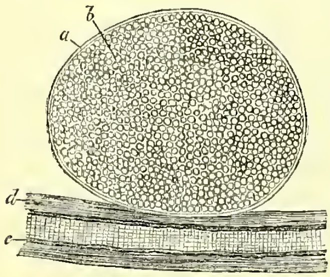


A small arterial trunk with Malpighian corpuscles, on a somewhat larger artery. From the spleen of the Pig. Magnified 10 *diameters.*

a, the artery; *b*, the sheath of the same; *c*, Malpighian corpuscles; *d*, pencils or tufts of arteries.

nected to the small arteries and their twigs by short peduncles, like the berries of a bunch of grapes; and, in such wise, that a small arterial trunk of from 2 to 4-100ths line, with its ramifications, supports 5 to 10 corpuscles. (*Fig.* 526.) The peduncles of the corpuscles are almost always small arteries, which pass to be distributed to them; but in less frequent instances, they are constituted by short processes of the arterial sheaths, which are continuous with the membranous wall of the corpuscle. In this manner the majority of the

Fig. 527.

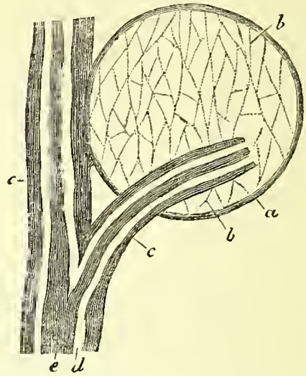


A Malpighian corpuscle from the spleen of the Ox in connection with a small artery, magnified 150 *diameters.*

a, wall of the Malpighian corpuscle; *b*, contents of the same; *c*, coat of the artery; *d*, sheath of the same.

corpuscles are essentially devoid of a peduncle, and sit immediately on the arteries at their points of bifurcation, or at their sides. (*Figs.* 527, 258.) This relation, which also obtains

Fig. 528.



Malpighian corpuscle from the spleen of the Pig in connection with an artery from which a branch passes to the corpuscle. Treated with soda, and magnified 250 *diameters.*

a, wall of the corpuscle; *b*, elastic fibres in the same; *c*, sheath of the artery; *d*, dissolved middle tunic of the artery; *e*, elastic inner coat.

in animals, formerly appeared to J. Müller as indicating the fact that the splenic corpuscles were hollow excrescences of the vessel-walls, or were imbedded in these latter. But if by this be understood, what Müller's plates and description imply, that the sheaths of the vessels, in their whole thickness, with all their elements, are continued to form the corpuscles, then it is certainly incorrect: for in some animals I have seen that, from the rich network of elastic fibres and muscular structure of these sheaths, little or nothing passes to the corpuscles: and I have generally found the membrane of the corpuscle very delicate. It is, however, quite conformable to truth, to state that this membrane has a direct continuity with the arterial sheaths. (*Fig.* 527, 528.)

The corpuscles do not possess any connection with the trabecular network, still less that which Gerlach has lately attributed to them: viz. that they serve as points of support to the elastic fibres of the partitions; a belief which is altogether baseless.

It is difficult to say any thing definite respecting the number of the splenic corpuscles. Hessling believes that, in some cases, they constitute from one-fifth to one-sixth of the whole splenic mass; and this seems to me no overstatement, if we substitute the expression "spleen-pulp" for "spleen-mass." At least, I have found, that their quantity is very considerable; and that in some instances, when they are rather turgescent, the whole pulp appears as if besprinkled with white. They stand so thickly together, that in many places they touch each other's sides; and in others are only separated from each other by narrow interspaces, which in the least favourable circumstances are about one to two lines in size. I believe that the estimate, that one and a half to two lines of spleen-pulp con-

tains one Malpighian corpuscle, is rather too little than too large.

As regards the lower animals, it would follow from my researches, that the Malpighian corpuscles occur in *Mammalia* in precisely the same way as in Man; at least, in more than twenty genera which I have examined, I have never found them to be absent. It has long been known that they are very distinct in pigs, sheep, oxen, goats, and so also in guinea pigs, hedgehogs, and bats, &c., in whom they are rather larger and more resisting than in Man; and although in the dog, cat, and rabbit, they are somewhat smaller and more covered by the pulp, yet they are nevertheless very distinct. As to *Birds*, Bardeleben seems to have recognised the Malpighian corpuscles in swallows, pigeons, and geese; while I have been able to verify their existence in sparrows, although they are not particularly distinct. So also Ecker briefly states, that he has seen them in birds; and Oesterlen mentions their occurrence in the fowl, pigeon, and in many of the *Raptores*. Amongst the *Reptilia*, J. Müller has detected them in the Chelonia; while I have seen them very distinctly in the anguis fragilis, in whom the corpuscles were surrounded by a beautiful network of capillaries. Amongst the *naked Amphibia*, Oesterlen states himself to have seen them here and there in toads and frogs; but in direct opposition to this, I have found no trace of them. Just as little have I been able to detect them in *Fishes*, although I have examined many of the fresh-water genera with this especial purpose. And thus the conjecture of Müller*, — that they exist in all the vertebrata, although in none so distinct or so easy of observation as in the vegetable-eating mammals — must be considered as incorrect: a cirumstance which is not without considerable interest in the determination of their import.

On inquiry into the more minute structure of the Malpighian corpuscles, it is exceedingly necessary to regard, not only their appearances in Man, but also in the lower animals. Each Malpighian corpuscle possesses a membrane and contents, and therefore is not a solid corpuscle, but rather a vesicle. The membrane which Malpighi beheld, was minutely described for the first time by Müller and Giesker. According to the first of these observers it is, as previously mentioned, a process of the common sheath of the vessels, which either immediately continues as a vesicular swelling of the same, or is previously produced into a peduncle. Giesker rejects this view, at least as regards the human subject, and describes in each corpuscle a peculiar, independent, and tolerably strong membrane, which seems to have no connection with the sheaths of the vessels, but receives an additional thin outer covering of white fibrous tissue, in which the vessels of the corpuscle ramify, and to which they frequently impart their own red colour. The majority of later observers have unconditionally adopted one or the other of these views; only a few of them, as J. Simon, Henle, Ecker, and Oesterlen, having taken the trouble of substantiating their truth by original inquiry. Henle, Oesterlen, and J. Simon, deny the existence of a special membrane. The first of these observers finds that the wall of the corpuscles is constituted solely of granules, under which appear to be comprised structures resembling the morphous part of the contents; while fine bundles of white fibrous tissue unite on their outer surface. Oesterlen and J. Simon likewise deny the peculiar membrane (limitary membrane), an absence which the latter associates with the capacity of the corpuscles to fill themselves out from the capillary vessels. So also Bardeleben describes a membrane very indistinctly.

* Physiologie, i. S. 486.

On the other hand, Ecker* has assured himself of the presence of a membrane in mammals and birds. By the application of potash, the masses of granules which seem to constitute the wall of the corpuscle were dissolved; and he then not only saw the ramifications of the arteries on the Malpighian corpuscle with great distinctness, but he also recognised that this possesses a distinct membranous wall, in which a network of exceedingly fine and well-defined stripes could be detected. Although these stripes are actual fibres, yet, according to Ecker, they everywhere cover a structureless gland-membrane, for the wall of the vesicle is never interrupted in the structureless intervals between these fibres; indeed it is possible that the latter are themselves but folds of a structureless membrane. Amongst the most recent authors, Arnold † and Huschke ‡ accept Giesker's view, and Dr. Gerlach § repeats Ecker's decision. As to myself, in the first place, I regard it as an incontrovertible fact, that the Malpighian corpuscles possess a special membrane. If one of the vesicles be isolated, and sufficiently separated from the surrounding tissues, it may be seen without any further preparation, especially with a slight pressure (*fig.* 527.); and it becomes particularly distinct if a little dilute soda or potash be applied (*fig.* 528.). These reagents dissolve all the surrounding parts of the pulp, with the exception of the vessels, and thus leave the membrane of the vesicle, although somewhat altered, yet quite entire. Concerning the nature of this membrane, I have verified the following: it is colourless, transparent, about 1 to 2-1000ths of a line in thickness, has everywhere two contours, and here and there it exhibits concentric lines. Its structure so far corresponds with that of the sheaths of the vessels with which it is continuous, that it contains at least white fibrous tissue and elastic fibres; but the unstriped muscular fibres which oc-

* Der feinere Bau der Nebennieren, 1846, S. 10.
† Anatomie, ii. S. 123.
‡ Eingeweidelehre, S. 178.
§ Zeitschrift für Rationelle Medicin, Bd. vii. S. 77.

cur in these sheaths in many animals, are altogether absent from the membrane of the Malpighian corpuscle; and the latter must especially be noticed as being much more delicate than the sheaths of the arteries on which the corpuscles sit. The white fibrous tissue, which Ecker regarded as a continuous membrane, in consequence of having seen it when changed by the action of potash, is in precisely the same condition as in the partitions and sheaths of the vessels, and forms by far the greatest part of the coat of the corpuscles; while the elastic tissue (the stripes of a doubtful nature which Ecker saw) appears to constitute only a more or less extensive network of pale, so-called nuclear fibres (kernfasern) (*fig.* 528. *b*). So that the membrane of the Malpighian corpuscles would thus appear to be only a modified portion of the vascular sheath, — a view which most approximates to that enunciated by J. Müller. An outer coat, of which Giesker speaks, has never been plainly verified by me as a special membrane connected with the preceding; but it seems to me more probable, that the corpuscles are always immediately surrounded by the cells and vessels of the pulp. Certainly these vessels are often connected together by an indistinct fibrous or membranous substance, but this is especially present in the pulp, and is nothing else than the termination of the sheath of the vessels. The preceding remarks especially apply to the Malpighian corpuscles of the higher brute mammalia. As to those of man, although they are much more difficult to examine, yet I have satisfied myself in the most positive manner that they correspond with those of the brute mammalia in all essential points. This is easiest and best seen in the spleens of children. The structure of these is exactly that seen in animals, only the coat is more delicate, so that it is extremely difficult to isolate a single corpuscle entire, and the contents are expelled by the slightest pressure. In the wall is seen the same network of elastic fibres as in animals, and this renders it possible even to recognise those which are burst. Extremely fine capillaries of 3-1000ths of a line in diameter may frequently be seen around the corpuscles; but the latter are just as little enveloped in a second membrane as in animals.

The Malpighian corpuscles do not possess in their interior an epithelium and separated contents like the glands, but they are densely filled with a semifluid, greyish white, cohesive mass (*fig.* 527. *b*). This contains, together with a small quantity of a clear fluid, a large quantity of morphous particles, which have been very differently described by different observers. According to J. Müller they very much resemble the corpuscles of the spleen-pulp, and have a general likeness to the blood discs, but are irregularly spherical. Bischoff regards them as altogether corresponding with those of the chyle, both in appearance, size, and behaviour with water and acetic acid. According to Henle, they resemble those of the spleen-pulp and those of the thymus and thyroid body; and he so describes them, that it would appear he recognised nuclei and a small proportion of cells. Oesterlen describes them as nuclei resembling the elements of the pulp. Hessling, Huschke, and Nasse* agree with Bischoff respecting the similarity of the elements in question to the lymph and chyle corpuscles. The latter of these authorities finds those of the rabbit to be 2—3-1000ths of a line in diameter, while Hessling certifies to their size in men as from 2—5½-1000ths, and describes their surfaces as possessing a mulberry-like appearance, and their contents as partly minute granules, partly separate nuclei. J. Simon found that the corpuscles in question never attained a development into cells. Remak† describes them as consisting — partly of large transparent cells, with an interior containing a single lateral, or double and clear nucleus — partly of small, dark-bordered vesicles, closely surrounded by a delicate pale membrane, and occupied by a dark central nucleus. The first, according to him, resemble the larger, the last the smaller lymph corpuscles. Finally, Gerlach finds in the Malpighian corpuscles the nuclei of cells, and, in equal quantity, cells of different sizes, with one, two, or three nuclei, as well as blood corpuscles, with all those forms of granule-cells which I shall hereafter describe as developed in the spleen-pulp from the effused blood.

These are the most important accounts given by others. As the result of my own researches, I must, firstly, corroborate J. Müller, who explains the elements of the contents of the Malpighian corpuscles and spleen-pulp as similar structures. Also, I can add with Bischoff, that they often resemble the chyle corpuscles; yet I am not disposed to lay any weight upon this correspondence. Furthermore, I consider it fully made out that Gerlach's view, according to which blood corpuscles, and cells which include blood corpuscles, are a constant constituent of the Malpighian corpuscles, is altogether erroneous. They are not even frequent occurrences, for in many animals I have not found them at all; and when they occurred — as, for instance, in oxen — they were mostly found in scattered vesicles, and, further, were in such small quantity, that they had no influence on their colour. And very often blood corpuscles and their metamorphoses appeared to occupy the vesicles, where a more careful examination showed that they were only in contact with their outer surface. The degree of accuracy to which Gerlach's assertion may lay claim is best shown by the fact, that he altogether denies the existence of these granule-cells (which are produced from the effused blood) in the spleen-pulp; while it is here, as well in these as in animals which possess no proper spleen vesicles, that they occur in

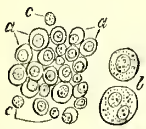
* Handworterbuch der Physiologie, von R. Wagner, ii. S. 387.

† Diagnostische und Pathogenetische Untersuchungen: Berlin, 1845.

the greatest quantity, and are most easily seen.

The constant and essential elements of the splenic vesicles are cells, with a single nucleus of a spherical shape, and from 3 to 5-1000ths of a line in diameter: besides these, free nuclei, and larger cells of 6-1000-ths of a line in diameter, and with one or two nuclei, also occur (*fig.* 529.). The cells are in general pale and faintly granular; their nuclei are from 16 to 25-10000ths of a line in size, spherical, apparently homogeneous, and with a rather dark margin; or frequently vesicular, with a more or less distinct nucleolus and other granules. It is not infrequent to see

Fig. 529.



Elements of the Malpighian corpuscles of the Ox, magnified 350 diameters.

a, smaller cells; *b*, larger cells; *c*, free nuclei.

single cells provided with dark fatty granules, and in particular instances blood discs are present, either changed or unchanged, free or included in cells. The free nuclei are of the same size as those contained in cells, and are also, in other respects, quite similar to them. In the ordinary method of examining the Malpighian corpuscles, the quantity of them nuclei seems larger than it really is, since many of the cells burst, and allow their nucleus to escape. Yet it is very remarkable that their number is very variable in the most cautious examination, a fact which appears to me partly to account for the very different statements of different observers. In many cases it has happened to me to find only a few free nuclei, often none at all, while in other instances they constitute a half or more of the elements of the corpuscles. This fact, taken together with the often very different size of the cells present, seems to prove that a continuous process of cell-growth exists in the Malpighian corpuscles; in such wise, that new nuclei and cells continually arise, and old cells perish. But hereof more will be said in speaking of the pulp, in which the same process obtains.

If, after these remarks, we take a glance at the import of the Malpighian corpuscles, we shall be compelled especially to ask ourselves, first, whether they are the beginnings of the lymphatics, or in any other way connected with them? and, secondly, whether they have the import of glandular vesicles? A connection of the Malpighian corpuscles with the lymphatics was a belief of many anatomists in earlier times, and in our own days has been recently upheld by Giesker, Huschke, Gerlach, and Poelmann. The acceptors of such a theory rest mainly on conjecture, but partially also on facts. Amongst the latter, there may be mentioned — 1. The correspondence of the cells in the Malpighian corpuscles with the lymph corpuscles. But we must remember that cells which correspond with the lymph corpuscles occur in many other situations where no such connection with the lymphatics can be imagined, as in the spleen-pulp itself, in the pancreas, in the salivary glands, the glands of mucous membrane, the thymus, thyroid, &c. 2. Huschke adduces the similarity of the spleen vesicles with the whitish granules of the lymphatic glands, which are dilatations of the lymphatic vessels themselves. Against this it need only be objected, that this latter is a pure fiction of Huschke's, and that even were it as he states, no conclusion concerning the nature of the Malpighian corpuscles could fairly be deduced from it. I have yet further to mention, that, according to an oral communication of Ecker which was made to me many years ago, and recently repeated, concerning the splenic vesicles of the mammalia, processes and pedicles exist which are neither blood-vessels nor partitions, and, therefore, may be lymphatics, — a view with which Poelmann's and Gerlach's recent statements are somewhat in unison. The former of these two * says that he followed the thoracic duct even to the Malpighian corpuscles, with which it became connected; but he does not specify more exactly the nature of this connection. The latter says that it has often seemed to him as if the neighbouring Malpighian corpuscles communicate with each other through special tubes; that he has been led to this belief by the circumstance that when the vesicles are compressed, their contents are expelled in definite directions, which a closer examination shows to be canals, the coats of which tolerably resemble in texture those of the Malpighian corpuscle; and that it is thence clear that the corpuscles communicate with a system of tubes which can scarcely be imagined to be any thing else than the lymphatics. And thus, if the Malpighian corpuscles are dilatations of the lymphatics, they may possibly be commenced as simple varicose swellings, or, what is more probable, as lateral productions of these vessels. I acknowledge that I am unable to verify this fact last adduced, or to subscribe to this connection of the Malpighian corpuscles with the lymphatics. In my researches I have given an attention to this point conformable to its great importance; and although I have not seen the commencement of the lymphatics in the spleen, yet I have so far come to a positive conclusion, that I am convinced of the complete closure of the Malpighian corpuscles. What Gerlach states of the tubes into which the contents of the corpuscles are forced, is altogether erroneous; such tubes nowhere exist. Gerlach appears to have been misled to this opinion by the fact, that when a corpuscle is burst by pressure, the contents rush out at several points,

* Annales et Bulletin de la Société de Médicine de Gand, 1846, p. 267.

and are then effused in the shape of long and small streaks in the surrounding tissues. If the commencements of such a streak were not observed, it might easily be regarded, from its always taking a radiating course from the Malpighian corpuscle to which it is united, as a canal communicating with the same, especially when a longer pressure applied to the corpuscles has elongated these stripes by continually forcing out the contents. The processes which Ecker has described on the Malpighian corpuscles, and which are not bloodvessels, probably belong to the same category as the artificial products mentioned above; or, if this is not the case, it is possible that they are small trunks of nerves, which are frequently present in the neighbourhood of Malpighian corpuscles, and which, from reasons that will be hereafter mentioned, are exceedingly difficult to recognise as being what they really are. I therefore maintain, quite plainly and definitely, *that the Malpighian corpuscles are closed capsules, and stand in no connection at all with the lymphatics.*

If this be so — and the structure of the Malpighian corpuscles, which altogether differs from that of vessels, corroborates the fact — it is next demanded may not the Malpighian corpuscles be glands? If by "glands" be meant the word in its ordinary sense, I answer with a decided "*no*;" for these altogether differ from the known simple shut glandular sacs of the ovary, thyroid, thymus, and supra-renal capsules, and possess neither a structureless membrana propria (limitary membrane, or basement membrane) nor an epithelium. On the contrary, in my opinion, they correspond with the spaces filled with cells in the lymphatic glands, and with the sacs of the glandulæ solitariæ and agminatæ of the intestine. Here and there hollow spaces exist, which possess a covering of white fibrous tissue, are completely inclosed, and contain in their interior no trace of epithelium, but only a coherent mass of nuclei and cells, together with some fluid; we might call these "*vesicular glands*," recollecting at the same time that they possess the function of the real shut glandular vesicles, although their anatomy essentially differs. Although the discussion of the former question does not belong to this part, yet I will add, that, in reality, there is much to indicate that the structures in question constitute a kind of shut glandular vesicle; and that, consequently, there is nothing to prevent their being regarded as glandular vesicles.

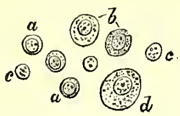
5. *The red spleen substance, the spleen-pulp, the parenchyma of the spleen* (*substantia rubra, pulposa, parenchyma lienis*), is a soft reddish mass, which fills up all the interstices between the larger partitions and the stronger vessels, and on section of the organ is easily scraped off or squeezed out. It consists essentially of three constituents; which are, fine bloodvessels, parenchyma cells of the spleen, and small partitions or fibres. To these constituents is so frequently added, both in man and animals, extravasated or coagulated blood in various metamorphoses, that one is almost forced to designate it a normal constituent. According to the predominance or diminution of the latter ingredient, or according to the greater or lesser distention of the bloodvessels themselves, the spleen-pulp appears sometimes altogether of the colour of the blood, at others of a clearish red, with a greater or lesser tendency towards whiteness.

The following remarks apply to the microscopic appearances of the constituents of the pulp, the vessels only excepted, which will be described hereafter. The fibres of the pulp are of two kinds. The one kind, which may be named "small or microscopic partitions" ("*microscopische balkchen*"), are quite analogous to those larger partitions ("*balken*") which are visible to the naked eye; they are also of the same structure, except that in the lower animals they often contain more muscular fibres than the latter. Their diameter is variable, from 5 to 10-1000ths of a line; their frequency and quantity also vary in different situations, and amongst different creatures. In the human subject I find them to be fewer and broader than amongst other mammalia, and exactly like the larger partitions in structure; while in the ox, sheep, &c., they occur frequently, are more delicate, and are remarkable by their purely muscular structure. The other fibres of the pulp are evidently processes from the sheaths of the larger vessels; they greatly predominate in quantity, and appear chiefly in the form of delicate membranes of an indistinctly fibrous structure, and without any mixture of elastic fibres, which seem to connect the capillaries to each other. Whether they take the form of small partitions — in which case they could not be distinguished from the small *trabeculæ* — is at present undecided. In animals, these membranes are also present on the veins; but of this more will be said hereafter, in speaking of the vessels.

The *cells of the spleen-pulp*, which I shall call "parenchyma-cells of the spleen," have been described by J. Müller as similar to those of the Malpighian corpuscles; and, as was previously stated, this view has been followed by the majority of writers; as by Henle, Bischoff, Huschke, Remak, and others. Only Von Hessling and Gerlach are of another opinion. According to the former, the globules of the spleen-tissue are distinguished by their dark colour, and by their being mingled with spindle-shaped cells. Gerlach finds that cells with nuclei are rare in the spleen-pulp; while, on the contrary, he considers them to be frequent in the Malpighian corpuscles. As to myself, I have already expressed my concurrence with the view taken by Müller, and may therefore forbear to enter further upon this point; nevertheless, it is necessary to remark that the parenchyma-cells exhibit some additional peculiarities, which ought not to be passed over without notice. A considerable portion of these cells completely correspond

with the cells of the spleen vesicles; the characteristic appearances of which are their

Fig. 530.



Parenchyma-cells from the spleen of the Ox, magnified 350 *diameters.*

a, Smaller cells; *b*, cells of medium size; *c*, free nuclei; *d*, largest cells.

roundness, their size — from 3 to 5-1000ths of a line — their paleness, and their dark nucleus (*fig*. 530. *b*). On the other hand, smaller and larger corpuscles also occur in the spleen-pulp, which are never met with in the Malpighian corpuscles. The former are small round corpuscles, somewhat larger than blood globules. They are seen in one of two states: either they exhibit a membrane and nucleus inseparable from each other, and thus, apart from their colour and somewhat lighter outline, resemble blood globules; or they are free nuclei, in which no nucleoli are visible. But only a few of these are free nuclei, for by the application of saliva or a little water a membrane starts into view, either completely enclosing them, or limited to one side (*fig*. 530. *a*). The nuclei, which thus appear as something separate from the membrane, have always the dark appearance of those cells the two parts of which are inseparable from each other; so that the appearance of these latter would seem chiefly dependent on the nucleus. With these small and quasi-developing cells, one also meets with free nuclei; and careful manipulation of the preparation shows these to be in general more numerous than in the Malpighian corpuscles (*fig*. 530. *c*). The larger named corpuscles are partly pale cells of 7-1000ths of a line in size, with one or two nuclei; or granule-cells of 4 to 6-1000ths of a line, and which may be described as "the colourless granule-cells" (*fig*. 530. *d*): both of these are more frequent than in the Malpighian corpuscles. The spindle-shaped or fusiform cells which Hessling mentions do not belong to the normal constituents of the spleen-pulp, and are nothing else than epithelium cells of the splenic arteries (*fig*. 534. *b*), which in macerated specimens of the human spleen, and in preparations where the vessels have been cut through, easily get into the pulp, and give rise to the delusive appearances of the so-called fusiform cells. The comparative examination of this part of the spleens of many animals confirms what has been already stated of the elements of the Malpighian corpuscles; namely, the elements of the pulp vary greatly, since sometimes the nuclei, sometimes the smaller cells, sometimes the greater cells, predominate. And in this, as in the former case, I conclude therefrom that a continuous process of cell growth obtains in the spleen, by which new cells are formed around nuclei, and old ones disappear.

The quantity of parenchyma-cells of different kind and shape, and of free nuclei which must be reckoned with these, is a very considerable one; so much so, as to constitute nearly one half of the whole red spleen substance. These do not lie collected in large heaps, but constitute small irregular groups of different size, which occupy the interspaces formed by the partitions of all sizes, the vessels, and the Malpighian corpuscles. The best method of representing this disposition is to regard each part of the pulp, which is included in a large mesh by trabeculæ visible to the naked eye, as constituting in a small form what the spleen itself is in a larger. The microscopic partitions and fibres and the finest vessels thus exhibit the same relations as the larger partitions and vessels; while the small nests of parenchyma-cells answer to the large homogeneous masses of red pulp which are visible to the naked eye. There are nowhere any special coats which include these cells, but they may be seen everywhere placed immediately on the sheaths of the vessels, the partitions, and the membranes of the Malpighian corpuscles. In the above delineation of the parenchyma-cells, those of man and of the higher mammalia have especially served as the model: but in general a complete similarity obtains in other animals; and it is only here and there that any specialities show themselves. In many animals — thus, for instance, in amphibia — the spleen has often, though not always, very beautiful parenchyma-cells with large nuclei: in birds, and in the scaly Reptilia, granulated and somewhat dark cells are for the most part more frequent. In the hedgehog, rabbit, and guinea-pig, some cells, which are altogether peculiar, occur in company with the ordinary ones. In both the former of these I saw, here and there, large round cells from 10 to 16-1000ths of a line, with three, four, to ten or more nuclei, which often lay so closely together in the middle of the cell that they appeared to make up a mulberry-like mass, like certain large cells which one finds in the marrow of young bones. These cells were by no means uncommon, but gradually diminished in size towards that of the parenchyma-cells. In the guinea-pig occur round cells, in large quantity, of 48 to 60-10000ths of a line, which contain one or seldom two round granules of a dark contour; and their nucleus, not always very distinctly visible, is very plainly seen on the application of acetic acid; while, at the same time, the dark granules often disappear.

The *blood effused in the spleen-pulp*, as well as the *metamorphoses of the blood globules* in the same, demand the greatest consideration both in respect of anatomy and physiology. I believe myself to have been the first who* directed attention to this circumstance, and cor-

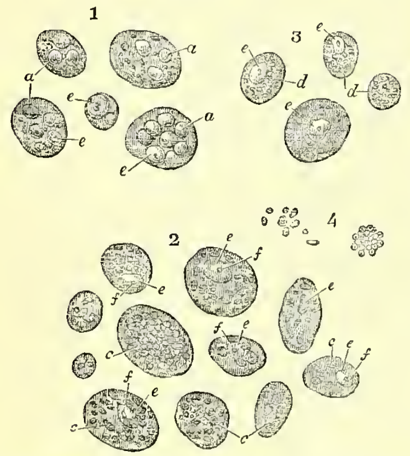
* Loc. cit.

rectly recognised it; although Oesterlen, Remak, and Handfield Jones had already detected isolated facts having a reference to it. Oesterlen * was the first who found in the spleen of frogs and toads, and with less distinctness in that of the mammalia, yellow, rose-red, and black minute corpuscles, but he was not in a condition to explain them. Remak followed next without greater success; he found in the spleen-pulp of the calf delicate transparent vesicles, with 1 to 3 round, reddish-yellow homogeneous bodies, the colour of which approximated to that of the blood corpuscles, but which were not so easily swollen out by water. Finally, Handfield Jones † discovered peculiar yellow corpuscles in the spleen of different vertebrata.

All these facts are placed in their true light by my discovery that blood corpuscles are almost constantly undergoing dissolution in the spleen and disappearing. This will be shown as follows: —

The red pulp of the spleen in man and animals exhibits at different times a different

Fig. 531.



Cells containing blood corpuscles from the spleen of the Rabbit, magnified 350 *diameters.*

1, cells with one, three, four, and seven unchanged blood corpuscles; 2, cells with blood corpuscles undergoing dissolution, and coloured in different shades of brown or yellow (coloured granule cells); 3, cells with destroyed and decolorized blood globules, larger or smaller, and with or without granules; 4, blood globules altered in colour, diminished or destroyed, either single or aggregated, in small clumps.

In 1, 2 and 3 the following letters signify alike: — *a*, more or less unchanged blood globules; *c*, colored granules begun by a diminution or destruction and alteration of colour in blood corpuscles; *d*, colourless granules produced by the discoloration of *c*; *e*, nuclei of the cells containing blood corpuscles and their metamorphoses; *f*, nucleoli of these nuclei.

colouring, or rather a different condition of the blood corpuscles contained in it, and these, without any participation of the other elements, affect its colour by the different nature of their appearances. Thus, in a particular animal or in the human subject, this substance sometimes possesses a paler or more greyish red, sometimes a brown, or even black-red colour: in the latter case a quantity of altered blood globules are present, the appearances of which will hereafter be described; while in the former case, it may easily be proved by the microscope that the red colour depends on unaltered blood globules, which are easily separated from the pulp by pressure, and on the application of water give off all their colour in a short space of time. In other animals, the spleen has always about the dark colour mentioned: nevertheless, even in these cases, sometimes only unchanged blood globules are seen; sometimes many of these are undergoing the most manifold changes.

Now these changes (*figs.* 531, 532.) are very extraordinary and peculiar, and in all animals depend essentially upon these facts. The blood globules first become at once smaller and darker, while the elliptical corpuscles of the lower vertebrata also become rounder: then, in connection with some blood plasma, they become aggregated into small round heaps; which heaps, by the appearance of an interior nucleus and of an outer membrane, experience a transition into spherical cells containing blood corpuscles. These are from 5 to 15-1000ths of a line in size, and contain from 1 to 20 blood corpuscles (*figs.* 531. 1. 532. 1.) During this time the blood corpuscles are continually diminishing in size, and, assuming a golden yellow, brownish-red, or dark colour, they undergo, either immediately or after a previous dissolution, a complete transition into pigment granules. So that these cells themselves are changed into pigmentary granule-cells; and, finally, by a gradual loss of colour of their granules, they form themselves into completely colourless cells (*figs.* 531. 3. 532. 4.).

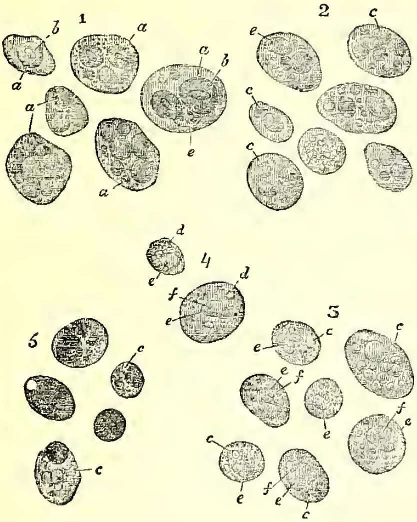
In respect of the more special circumstances of this process, it is first necessary to consider the commencement of the cells described, and their changes, somewhat more in detail. As regards the first of these, it is certain that the cells containing the blood corpuscles do not commence directly around a nucleus, but by the circumposition of a membrane around a heap of coagulated blood: in the same way, to wit, that the so-called inflammatory globules of Gluge in certain cases change themselves to cells; or that by which the smaller globules of fission of the yolk form themselves into vesicles. On the other hand, it remains doubtful whether the nuclei which are seen in these cells are there before the formation of the membrane, or whether they only begin as supplementary to it. If the former be the case, one might add that, in the extravasated or clotted blood of the spleen, nuclei arise in consequence of the commencing organization, each of which then, like the nuclei in the fission of the yolk,

* Loc. cit. p. 52.

† London Medical Gazette, Jan. 1847, pp. 140-142.

surrounds itself with a part of the blood (plasma and globules), and, finally, con-

Fig. 532.



Cells containing blood corpuscles, from the spleen of the Frog (Rana temporaria and esculenta), magnified 350 *diameters.*

1, cells with one or more blood globules of an intense yellow colour, diminished in size, yet mostly not yet destroyed; 2, cells with blood globules coloured brown, orange, or black, still more diminished and dissolved (coloured granule cells); 3, cells with blood globules much diminished or quite dissolved, and undergoing discolorization (pale-coloured granule-cells); 4, cells with completely dissolved and discolorized blood globules (colourless granule-cells); 5, coloured granule-cells (like those in 3) in different stages of their transition into black pigment-cells.

In 1—5 the letters import, as in *fig.* 351. *b*, the nuclei of the blood globules.

ditionates the development of a membrane on the surface of the sphere thus commenced. Or one might regard the formation of spheres consisting of some blood plasma and blood globules as the primary phenomenon; and that then a nucleus begins in each sphere; and that, finally, a membrane is thrown around these. In corroboration of this opinion, Hasse and myself* have observed in the pigeon the occurrence of inflammatory globules, which are without nuclei or membranes, but contain blood globules; and to this may be added, that in the splenic extravasations blood corpuscles are often grouped together in heaps without being contained in cells. Be this as it may, in any case thus much is certain, that as soon as the cells with their included blood globules are visible, the nuclei are never absent; and this fact, taken in conjunction with what is already known of the import of nuclei in the process of cell development, speaks strongly for their formation preceding that of the membrane of the said cells.

These cells containing blood corpuscles behave themselves so far alike in all creatures, that their blood corpuscles by degrees disappear and fall to the ground; and, ultimately, they all seem to be converted into colourless cells, although the methods by which this change occurs are different in different animals; whence it will be well to go through them one by one.

a. In *mammals* the cells with unchanged blood corpuscles are not very easily seen, on account of the small size of the latter, and the facility with which they lose their colour; yet one can easily get a sight of them, provided the examination be made at the right time, and the application of water forborne. I have seen them plainly in man, the rabbit (*fig.* 531. 1.), guinea-pig, sheep, calf, and dog; and have found that in these creatures the number of the included blood globules is from 1 to 12, on an average from 2 to 6, and the size of the cells from 5 to 16-1000ths of a line; while their vesicular nuclei have a length of 36-10000ths, and a breadth of 28-10000ths of a line. By the shrinking up and falling to pieces of the blood globules, which immediately renders them darker in colour, coloured granule-cells begin from these cells. They are of a golden yellow, or rusty or brownish yellow, or even blackish colour (*fig.* 531. 2.), and gradually experience a transition into cells, with slightly coloured, more numerous, and smaller granules; and, finally, they take the form of altogether colourless cells, part of which are even poor in granules (*fig.* 531. 3.). In man, the rabbit, and the guinea-pig were found, besides the cells just described, free granules and heaps of granules, of a golden yellow, brown, or blackish colour; together with altered blood globules, concerning which it seemed to me very probable that they were originally free, and were never included in cells. In other vertebrata, as in the hedge-hog, the cat, and the bat (*Vespertilio myotis* and *pipistrellus*), the cells with the unchanged blood globules were not observed, although all other stages, from the golden yellow to the altogether colourless granule-cells, were seen. Finally, in others, as in the horse and ass, were seen uncommonly numerous, diminished, and highly coloured blood-globules, both isolated and aggregated; and the metamorphoses of these into golden, brown, and blackish-yellow heaps of granules, although no definite indication of cell structure could be detected around these heaps.

b. Amongst *birds*, I have found the round cells in Falco albicillus, Cuculus canorus, Turdus varius, Perdix saxatilis, and Sylvia hortensis. They were in larger or smaller quantity, from 4 to 10-1000ths of a line in size, with dark golden yellow granules which were evidently nothing but metamorphosed blood globules. This was very distinctly shown in Turdus musica, since here the cells occurred with unchanged blood globules. Everywhere these cells experienced a transition, partly into brown and black granule-cells, partly into colorless granulated cells.

c. Amongst the *Reptilia.* In the *scaly*

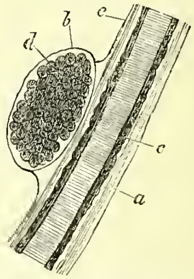
* Zeitschrift für Ration. Medicin, Band. iv. S. 1.

Reptilia, amongst which I have only examined Anguis fragilis and Coluber austriacus, I have seen no cells with unchanged blood globules ; but in the Anguis I found pale yellow, brown, and black granule-cells, which were, as in birds, of from 6 to 10-1000ths of a line in diameter. Transitions of these into faintly yellowish and colourless granule-cells were also present in considerable number, being almost as frequent as the ordinary parenchyma cells in the spleen-pulp. The Coluber austriacus certainly exhibited an effusion of blood in the parenchyma of the spleen, but no changes of the blood corpuscles. The *naked* amphibia offered a striking contrast. Amongst them I examined Rana temporaria and esculenta, Bombinator igneus, Hyla arborea, Bufo cinereus, Alytes obstetricans, Salamandra maculata and atra, Triton igneus, tæniatus, and cristatus. The cells with blood globules were better seen in these than in any other animals. This was especially the ease in Triton, Bombinator, and Rana, in which 5, 10, 20, and more blood globules, with distinct nuclei, were frequently seen occupying a plainly nucleated cell of 6 to 12-1000ths of a line in diameter. The size of the blood globules in these cases allowed their metamorphoses to be followed through all stages, as is represented in *fig.* 532. At first they were round, of an intense yellow, and less easily altered by water ; then they contracted themselves yet more together, assumed a golden yellow or brown yellow colour, and were no longer assailed by water ; finally, they became colourless, or experienced a transition into black granules, while they generally also fell asunder into smaller granules. In this manner golden and brownish yellow granule-cells (*fig.* 532. 1.) arise from the cells with unchanged blood globules (*fig.* 532. 2, 3, 5.), and finally they experience a transition into colourless granule-cells (*fig.* 532. 4.), or exist for a longer time as black pigment cells.

d. In *fishes* I have recognised the same conditions as in the naked amphibia, only they were not so brilliant. The cells with blood globules were very distinctly seen in Salmo fario, Cyprinus carpio and brama, Tinca chrysitis, Esox lucius, Perca fluviatilis, Coregonus muræna, and Gadus lota. In Anguilla fluviatilis, Aspius alburnus, Chondrostoma nasus, leucocephalus, &c., they were less plainly seen; nevertheless, cells with shrunken blood corpuscles, or aggregates of such, occurred also in these. In all fishes these structures become converted partly into colourless granule-cells, partly into black pigment-cells and pigment masses, which finally often lose their colour.

The *place* where the changes of the blood corpuscles above mentioned occur can be demonstrated in some amphibia to be the bloodvessels. Thus, in Triton igneus, the spleen is at its margins tolerably transparent, and here one frequently comes upon the cells which contain blood corpuscles, occupying the capillaries in a row one after another ; and here we are also able to drive them into the larger venous channels by pressure, so that one of these is often filled by a considerable streak, consisting entirely of these altogether characteristic elements. Whether this occurrence is a rule in the Triton, and whether it obtains in other amphibia, I am unable to certify. Yet I may communicate that, in the Triton, frog, toad, and Salamandra atra, I have found these cells containing blood corpuscles even in the trunks of the splenic vein and vena portæ ; while in Bufo cinereus, Triton igneus, and Salamandra, I have found them in the hepatic branches of the vena portæ, even to its capillaries ; and in the latter animal, even in the inferior cava and the heart. In any case, these facts may be considered as conclusive of the not unfrequent occurrence and formation of the cells in question within the bloodvessels of the spleen ; although it can scarcely be added that they are not probably also formed in the extravasated blood. In certain genera of fishes, as in Tinca, Esox, Perca, the cells which contain blood corpuscles, and their metamorphoses, are seen included in round delicate-walled vesicles of from 1-40th to 1-16th of a line in diameter (*fig.* 533.), which for the most part

Fig. 533.



Artery (*a*), *with a cyst* (*b*) *in its tunica adventitia* (*c*), *which contains cells* (*d*) *enclosing blood corpuscles. From the spleen of the Tinca chrysitis.*

sit on the ramifications of the splenic arteries, either laterally on the vessels, or on the points where they divide ; and which are connected with the sheath or exterior membrane of the same ; or, in other words, are nothing else than *pouchings* of the same. How these vesicles are developed I have not determined, yet I can scarcely doubt that they have the import of false aneurisms, and owe their origin to a tearing of the inner and middle tunics, and to a protrusion of the tunica adventitia, together with the sheath of the vessels (if the latter texture can be supposed to exist here). The similarity of these vesicles with the Malpighian corpuscles of the mammals seems to be especially worthy of mention. After the description already given of the relation of the Malpighian corpuscles to the arteries, it is unnecessary to explain in detail, that the correspondence of both in respect of their site is very great. But, in respect of their contents a similar resemblance is sometimes exhibited, when, as in the cysts of fishes, the cells with blood corpuscles

have all undergone a transition into colourless cells, or the Malpighian corpuscles contain effused blood. By pondering upon these circumstances, one might almost come to the idea of regarding the cysts of fishes as Malpighian corpuscles, or the Malpighian corpuscles of mammals as false aneurisms of the splenic arteries; but in my opinion either of these views would be altogether erroneous. For although blood is often present in the Malpighian corpuscles, yet this appearance is *much too seldom* to allow of our explaining their contents as arising out of altered blood. And as regards the cysts of fishes, they are altogether absent from many fishes, and, where they are present, often undergo a cretification, or are changed into concretions; while they occur in other organs, as for instance in the kidneys: facts which have little conformity with the constant occurrence of the Malpighian corpuscles. In others of the fishes previously mentioned, no vesicles can be recognised in the spleen; on the contrary, in many genera, the blood corpuscles obtained in different conditions of their metamorphosis are seated together in roundish heaps of a more or less definite outline, and of a size which equals that of the vesicles: these are evidently nothing else than extravasations of blood. The numerous circumscribed red or brown points which occur in the spleen pulp of all fishes, are nothing but the self-decomposing blood globules; and they are, as above mentioned, either free or arranged in masses which are included in vesicles. In the scaly reptilia, birds, and mammals, it is very difficult to state with certainty in what part of the spleen the formation of the cells which contain the blood corpuscles and their metamorphosis occurs. At first I thought of the hollow interspaces with which the vein of the spleen begins; only these spaces, as will be shown hereafter, do not in the least obtain in the human subject in the form which has been hitherto attributed to them. Or the branches of the veins, which are always large, might easily be regarded as the locality, provided that the occurrences above mentioned be not regarded as extravasations. With regard to this question direct observation teaches us as follows. In the capillaries and arteries of the spleen in mammalia no changes of the blood corpuscles exist; so that the only question is, whether the blood corpuscles, which constantly occur in the spleen-pulp, and here undergo their metamorphoses, are situated in the commencements of the veins; or whether they occupy spaces newly formed by the extrusion of the blood. Much may be adduced in support of the first of these views. Thus, it is scarcely possible to suppose that extravasations of blood in such extraordinary quantity constantly occur in the spleen; then it may also be mentioned that pigmentary granule-cells, such as are developed in the spleen from the blood, may also be found in blood-vessels exterior to the spleen, which seems to speak for their being situated within the vessels in the case of the spleen itself. I have myself formerly found scattered pigment-cells in human blood * which I can now only regard as granule-cells from the spleen. Ecker has also seen † in the splenic veins of the calf, cells containing blood corpuscles like those in the spleen. And, lastly, Meckel ‡ has also found black pigment-cells in the blood of a woman whose spleen abounded in them. Finally, we may recollect, that in the amphibia the cells in question are certainly situated in the vessels. But, on the other side, it must not be forgotten that in the spleen of fishes metamorphoses of the extravasated blood take place, and that also portions of the extravasations enter the vessels, and that it is possible the pigment-cells in the blood may thus originate; finally, that the masses of blood in the spleen-pulp are scarcely defined with the sharpness which they would possess even in veins with very delicate coats. In this state of things it is much better to abstain from giving a definite decision; or if one be absolutely required, to attribute the metamorphoses of the blood in the spleen of mammals to both the localities mentioned.

The changes of the blood globules in the spleen are not exactly similar in all circumstances, either as regards the quantity of the cells thus changed, or the degree of metamorphosis which they undergo. In *fishes*, all the blood globules, without exception, may be recognised as decomposing; yet the quantity of these varies, *i. e.* the number and size of the vesicles and masses previously described varies in a considerable degree in different individuals and species, although no very definite laws have as yet been found out. *Reptilia* exhibited the following peculiarity. In newly-caught individuals, the cells containing blood corpuscles were very numerous and distinct; but in those which had fasted one, two, or three days, they occurred in exceedingly small quantity; while, finally, by a longer duration of the fasting (a week or more), they exhibited themselves in very great number, and of extraordinary distinctness; while at the same time the spleen became large, dark red, and very rich in the normal blood corpuscles. When newts which had fasted a week were fed, the cells previously existing, and the unchanged blood corpuscles, vanished, since they were changed into colored granule-cells, and only on the sixth day after the feeding did such cells reappear; but in three days afterwards almost all of these had again experienced a metamorphosis into granule-cells. In *mammalia* I have, in a series of cases, seen the decompositions of the blood corpuscles in as little as five, six, and more hours after eating, while immediately after the reception of food, or after a day's fasting, I have failed to observe it. At my advice, Landis § instituted experi-

* See also Fahrner, De Globulorum Sanguinis origine: Turici, 1845, p. 26. fig. 143.

† Zeitschrift für Rationelle Medicin, Band vi. S. 264.

‡ Zeitschrift für Psychiatrie, 1847, S. 22.

§ Beiträge zur Lehre über die Verrichtungen der Milz: Zurich, 1847.

ments concerning this on thirty rabbits, and obtained the following results. Of fifteen animals which were examined, two, five, and eight hours after eating, cells with unchanged blood globules were found in eleven ; in five they were in masses ; in six separate ; in four cases they did not occur at all. Fifteen other animals, which were killed twelve, twenty-four, and forty-eight hours after eating, showed in eleven cases no trace of the cells mentioned ; in two cases many were present, in two cases a few only. And, *vice versâ*, golden yellow granule-cells (*metamorphoses* of the cells with unchanged blood globules) occurred fourteen times in the latter animals ; ten times in great quantity, once in considerable numbers, and three times very sparingly, while in one instance only were they altogether wanting. In the fifteen animals first mentioned these were twice absent, five times sparingly present, twice in considerable numbers, and six times in large quantity. The conclusion to be deduced from these facts is, that cells with unchanged blood globules only show themselves a short time after eating, and that the granule-cells which proceed from these are almost always present, although in greater number in animals which have fasted a considerable time. If any animal were examined at the proper time, one would be astonished at the uncommon quantity of decomposing blood globules; for in such a case the whole red part of the pulp consists (so to speak) of nothing but golden yellow or blackish corpuscles, which are the different metamorphoses of blood corpuscles already mentioned.

Of the *ultimate destiny* of the blood corpuscles so metamorphosed, thus much is certain,—that they are decomposed and dissolved ; but, on the other hand, it is difficult to make out what is the destiny of the cells which usually enclose them We have already seen above that these cells occur in the splenic vein, the vena portæ, and the inferior cava, and it is thence questionable whether all these cells may not possibly pass into the blood. It is difficult to give an answer to this. Thus much I consider to be made out : —that cells with unchanged blood globules, and yellow, brown, or blackish-yellow granule-cells, only exceptionally and seldom pass into the blood of the splenic vein, or beyond ; since, in the first place, these cells are, upon the whole, rarely found in the blood ; while, secondly, their occurrence in the spleen is demonstrably very frequent. On the other hand, as to the colourless granule-cells which finally arise from the cells containing blood corpuscles, it is not made out whether they remain in the spleen or enter the blood. Supposing the first of these to be the case, they may either abide a considerable time in the pulp, and then in a certain manner serve as parenchyma-cells, with which they have a great similarity, or they may experience a dissolution, and altogether disappear. In the second case, one may imagine that they are converted into lymph corpuscles, with which they have, to some extent, a great similarity, or that they undergo a solution in the blood of the portal vein and the rest of the circulation. I own that I cannot hazard a decision. It is certain that colourless granule-cells occur in the blood as well as in the spleen ; but it is also certain that they are much more frequent in the spleen, and that, as regards the blood of extravasation which undergoes metamorphosis, it may be definitely stated, that its products for the most part remain in the same place.

So much for my experience of the decomposition of blood corpuscles in the spleen. Simultaneously with myself, Professor Ecker, of Basle, made similar observations, which likewise referred to a destruction of blood corpuscles, and which, soon after, lent an additional light to mine.* In contradiction to this, however, Gerlach has lately uttered the opinion that my observations allude to the formation of colored corpuscles within colorless ones ; so that he explains the forms of cells which are found in the spleen in precisely the reverse way, and supposes that the cells with golden yellow granules are the younger, and those with unchanged blood corpuscles the elder ; that is, that they are those in which the blood corpuscles have completely developed themselves, and from which they are ready to be expelled or set free. So that if Gerlach be correct, the relation of the blood corpuscles to the spleen is precisely the reverse of that which I have stated, and they begin there in great quantities ; and it thus becomes important to inquire whose opinion is the correct one. But if my experiments upon the behaviour of the blood corpuscles in the spleen have no other consideration, this merit, at least, remains to them, that they accurately set forth the anatomical facts, and in this manner have already sufficed to refute such false theories as that of Gerlach. In point of fact, Gerlach is altogether wrong when he supposes that the golden yellow granules are changed into blood globules ; for this can in no way be proved, but very easily the contrary. He is equally in error in adducing, as a ground for this view, that blood corpuscles begin as cells in the embryonal liver,—a statement which is altogether incorrect. And when he finally adduces that since, according to Harless †, the blood corpuscles are destroyed by the alternating influence of nitrogen and carbonic acid, a second kind of solution of these in the spleen cannot be conceived ; it need only be remarked that this theory of Harless's is not in the least proved as regards the living organism. So, also, Virchow ‡ has expressed himself as partially against mine and Ecker's account ; since, though he does not at all doubt the dissolution of blood corpuscles, yet he altogether denies the origin of cells around

* Loc. cit.

† Ueber den Einfluss der Gase auf die Form der Blutkugelchen : Erlangen, 1846.

‡ Archiv für pathologische Anatomie und klinische Medicin, Band i. SS. 452. 483.

heaps of blood corpuscles. This statement is only explicable by supposing that the Mammalia and Reptilia, in whom this phenomenon can be seen as plainly as could be wished, were not examined by Virchow. Besides, I do not maintain that the effused blood always forms cells containing blood corpuscles ; only I hold it as a fact established beyond all doubt, that this very frequently happens in the spleen as well as in extravasations in the lungs, lymphatic glands, brain, and thyroid body ; and while I believe that the formation of cells around these several effusions is not an equivalent fact, yet it is altogether certain that blood globules enclosed in cells undergo a more speedy dissolution than if they remain free.

In conclusion, one word concerning the import of the changes of the blood corpuscles in the spleen. It may be asked, whether they constitute a normal and physiological, or a pathological appearance ? On the one side, very weighty grounds may be alleged for the normal character, especially their (so to speak) *constant* occurrence and innumerable quantity in such a number of animals living in their natural condition, as the amphibia and fishes were. Furthermore, the apparently complete health which existed in spite of the vast quantity of dissolving blood globules. Thirdly, in Reptilia, the cells containing blood corpuscles may be seen in bloodvessels which are in no way isolated from the general circulation. Fourthly, similar and constant changes of the blood repeated at short intervals are absent from other organs of birds, mammals, and reptiles ; and many other arguments might be adduced. But, in contrast to these facts, many others appear on a more careful contemplation, which may almost lead to the opinion that all the changes of the blood globules in the spleen are possibly only pathological appearances. In fishes, dissolutions of the blood corpuscles occur not only in the spleen, but in an exactly similar way in other organs, namely in the kidneys, the liver, and the peritoneum. In the first of these organs their presence is *constant ;* at least, in the examination of many examples of eel, pike, Coregonus muræna and muræenula, Salmo fario, Barbus fluviatilis, Cyprinus brama and carpio, and Tinca chrysitis, not only were they always present, but almost always as numerous as they were observed to be in the spleen. In the peritoneum and the liver they were sometimes scarce, sometimes frequent, but only in the carp and Tinca chrysitis were they constant ; in other fishes they were either altogether absent, or only occurred here and there, as in the trout. If to these facts be appended that in certain animals,—to wit, in cats, sheep, and others,— the changes of the blood corpuscles in the spleen are very seldom observed, one can scarcely resist the notion that the appearance is abnormal ; and this is much more the case when one considers that similar appearances which are known not to be physiological, constitute almost constant occurrences, and are associated with exactly parallel changes of blood globules. Of this, the small effusions of blood in the lungs, bronchial glands, and thyroid bodies of men, and those of the lymphatic glands and mesentery of pigs and rabbits, are instances. But this latter view is insusceptible of full explanation ; for although pathological effusions and metamorphoses of blood often constitute almost a constant occurence, yet, first, the quantity of blood globules which undergo dissolution in such effusions is in no comparison at all with that of the millions which are destroyed in the spleen ; and, secondly, it has yet to be shown that effusions of blood may not occur as a physiological phenomenon, as happens in the bursting of a Graafian follicle in the ovary, in menstruation, and in the separation of the placenta. And although all animals do not show in the spleen such a solution of the blood corpuscles as can be verified by the microscope, yet it is by no means proved therewith, that where this takes place it depends on a pathological condition ; indeed, the blood corpuscles of different animals may undergo dissolution in different ways. At least thus much is certain, that in all animals, without exception, stagnations of blood occur in the spleen ; and I might add, almost of a certainty, in mammals, extravasations also. In these stagnations, the blood globules may dissolve themselves in the one case *rapidly*, in the other case *slowly*, and thus, according to the outer phenomenon, a *difference* will be produced. Such an occurrence may be *physiological*, since it is, at least in many animals, visibly *constant* and very extensive ; and it may have the greatest signification to the life of the organism. Therefore, so long as the pathological character of the phenomenon is not proved of a certainty, I am disposed to hold fast by its physiological nature, and to consider the dissolution of the blood corpuscles in the spleen as a normal fact.

6. *Bloodvessels of the spleen.* — The *splenic artery* (*arteria lienalis*) springs from the cæliac axis, and courses with many windings between the layers of the gastro-colic ligament until it reaches the fundus of the stomach, where it enters the gastro-splenic ligament, after giving off some small twigs to the pancreas and the stomach. Arriving in the neighbourhood of the hilus lienalis, it divides into a superior and an inferior branch. The upper of the two, passing somewhat upwards, and giving backwards from two to six short arteries (*vasa brevia*) to the large extremity or pouch of the stomach, divides into from three to six branches, which, lying in a line one over another, extend to the hilus, into which they enter. The inferior branch is somewhat larger than the others ; it passes to the inferior and anterior part of the spleen, supplying it with three to six branches, which enter the hilus in the same manner as the others, and it ends finally as the gastro-epiploica sinistra. Thus, all the six to twelve branches which enter the spleen lie tolerably

in one line upon each other in the gastro-splenic omentum, and they are also connected to each other by fat and areolar tissue. The size of the splenic arteries is very considerable in proportion to that of the organ, and so also the thickness of their coats is worthy of notice. In the first of these respects, it is possible that only the thyroid gland exceeds the spleen; the liver, which is so much larger than this organ, being supplied by an artery of scarcely larger size than the splenic, although we must not overlook the fact, that beside this the liver receives very much additional blood through the vena portæ. In the mammalia generally, the splenic artery is proportionally smaller than in men; this possibly depends only upon the more considerable contraction of the vessel at their death. Wintringham finds that the thickness of the arterial coats is greater than that of the aorta above the giving off of the renal arteries, to which it bears the ratio of 1 to 0·762; he also states that they will sustain a pressure of 41 lbs.

The serous covering of the spleen receives some unnamed small arteries: thus a twig is given to it from the left inferior phrenic artery, which courses in the phrenico-lienal ligament; and, besides this, it receives branches from the first lumbar, from the left spermatic, and from the splenic itself. Additionally to these, in some of the vertebrata, to wit in the calf, small twigs in great number leave the substance of the spleen, and after perforating the fibrous coat of the organ spread themselves out upon its surface.

The *splenic vein* altogether corresponds in distribution to the splenic artery. So many primary arterial branches enter the hilus of the spleen, and just as many veins come out of it. These six to twelve veins unite into two branches, and receiving, the upper the venæ breves from the stomach, and the lower the vena gastro-epiploica sinistra, they constitute the trunk of the vein. In the spleen, and at their emergence from it, the veins lie anterior to the arteries, but then they place themselves posteriorly to them; and it is behind the arteries that they unite to form the common trunk. This trunk receives a twig from the pancreas, from the lymphatics of the spleen, from the stomach, and, further, the vena coronaria ventriculi; it then passes away over the aorta to the under surface of the liver; and, finally, with the vena mesenterica superior it constitutes the trunk of the vena portæ.

The splenic vein, like all the branches of the vena portæ, has no valves, and is the largest branch which assists to form that trunk. Its width is very considerable: according to E. Home* and Giesker, the proportion to that of the arteries is as 5 to 1; and according to earlier authorities it is yet more. The proportionate size of the branches is still larger; and, according to C. A. Schmidt, their ratio in the spleen itself to that of the arteries which run with them is as 20 to 1. In contrast to this, the thickness of their coats is very inconsiderable, and, according to Wintringham, is to that of the arteries as 1 to 4·8 or 4·3, to that of the iliac vein as 1 to 3·5.

On their entry into the spleen, both arterial and venous branches receive as a covering a process of that "tunica propria" of the spleen which forms the *vaginæ vasorum*, previously described.

These are not alike in all animals: thus, for instance, they differ in man from those exhibited by the higher brute mammalia — a fact which explains the various descriptions given by different authors. In man, the sheaths of the vessels form *complete* coats around them. A section made in the centre of the hilus, and continued through the spleen, exhibits them very distinctly as projections or processes of the tunica propria, and also allows their further circumstances to be seen. It is thus shown that arteries, veins, and nerves are thickly enclosed in these sheaths; but in such wise that they are easily separated and isolated, especially in old, or macerated, or boiled spleens. The arteries and nerves allow of this more easily than the veins, which latter have a closer connection to these sheaths. It is further seen that not only are the trunks of entering and emerging vessels thus covered, but that their finer ramifications receive a similar clothing. The thickness of these sheaths is in the human subject by no means inconsiderable. As Giesker correctly states, they are at first exactly the thickness of the tunica propria, and retain the same thickness for a considerable distance, that is, as long as they clothe the main trunks of the vessels. On the branches which proceed laterally from these trunks, and on their further extent, the sheaths become naturally finer, and gradually increase this fineness as the vessels become more minute, until finally, becoming very delicate, they lose themselves in the pulp of the spleen in the manner previously mentioned. The thickness of a sheath is always less than that of the coat of the artery which it incloses, and greater than that of the vein; yet this does not hold good of vessels in all parts of their extent, since on the finest branches the sheaths are proportionally somewhat stronger than on the larger ones. As to the relations of the sheaths to the rest of the spleen substance, it must especially be considered that they do not lie free in the parenchyma of the organ, but are connected with the general trabecular network by means of balks which are given off from them: but these balks are not so numerous as different anatomists appear to think; so that we are scarcely entitled to consider with Giesker, that the whole trabecular network is formed out of this connection.

In other Mammalia, as in the horse, ass, ox, pig, sheep, &c., the course of these sheaths differs in some respects from that seen in man. In the three latter animals, which in this respect are best known to me, no

* On the Structure and Uses of the Spleen, Phil. Trans. for 1808.

sheaths at all are found on the smaller veins, and on the larger they are chiefly found on that side on which the arteries and nerves which accompany them lie. Only the two primary trunks of the veins which proceed from the spleen have for a very short distance a complete sheath, while all the arteries, even the finest, possess one; a condition of which more will be said hereafter.

The minute structure of the sheaths of the vessels in man altogether correspond with that of the partitions; and this holds good of animals generally. But I have not been able to detect unstriped muscular fibre in the sheaths in all those cases in which I have found it in the trabeculæ. In oxen this is especially the case; while, on the contrary, in pigs, &c., they are very plainly present.

Great difficulties oppose the inquiry concerning the distribution of the vessels in the spleen itself: since, 1stly, injection or inflation of the vessels gives little result on account of the delicacy of the organ; and, 2dly, great difficulties are connected with the microscopic examination of the organ. What will be now adduced concerning it is especially the result of the latter method of inquiry, which, combined with fine preparations by the knife, has seemed to me to be the most fertile in results.

When the main branches of the splenic artery have entered into the spleen they lie in their sheaths, each in company with a vein, to which they are posterior and inferior: they are in tolerably loose connection with the sheath, and not unfrequently they take a serpentine course. In their further distribution they do not behave as arteries generally do, which continually give off smaller branches, but they divide immediately into a quantity of different large and long branches in the manner of a shrub; of these the larger branches go to the anterior, the smaller to the posterior, margin of the organ. Beside this, it is especially to be remarked of the arteries of the spleen, that their different branches form no anastomoses. Assolant tied a branch of the splenic artery in a living dog, and then allowed the spleen to return into the cavity of the belly. The dog died thirty hours after: much inflammation and exsudation of a bloody serous fluid was found in the belly, and the spleen was quite healthy; only the part cut off from the circulation of the blood was gangrenous, and, as it were, separated from the sound part by a line of demarcation. In contrast to this, Heusinger tied all the branches of the splenic artery, one only excepted; upon dissection, the whole spleen was found to be mortified, excepting the part in which the artery not deligated ramified. Also injections in an artery always return solely by the corresponding branch of vein; and they only fill that region of the spleen in which the branch ramifies, never passing over into any other. I am unable from my own experience to pass any judgment upon these data, and will therefore not impugn them; but I may be allowed to doubt whether the capillaries of the pulp are completely separated from each other, and am more inclined to believe that, in consequence of the anatomical circumstances of the pulp, such a separation must be considered as impossible; since in the spleen we have before us, not a gland with special lobes separated from each other, but a parenchyma everywhere united. The above results of deligation and injection by no means necessarily imply an isolated course of the capillaries, and are fully explained by the supposition that the arteries possess no anastomoses.

When the arteries have divided into small vessels of 1 to 2-100ths of a line, they come into contact with the Malpighian corpuscles in the mode already described; while they are also connected to these by their sheaths. According to Giesker, their final terminations are coronal or pencil-shaped, radiating so as to surround the Malpighian corpuscles, and altogether enclose them; then arriving at the highest point of the vesicle, they return upon themselves in the shape of a loop, course back again as veins, and there meet together, beneath the point whence the artery radiated, to form a vein, which enters the same sheath from which the artery emerged. At this point the sheath divides into three to four fibrous threads, which pass over on the spleen corpuscles to the threads arising nearest to them, and unite with these. If we compare with this description of the minute anatomy of the spleen that which is considered most admissible by J. Müller, the next author after Giesker, we shall find very considerable contradictions. J. Müller finds that the smallest branches of arteries partly continue on the side of the corpuscles without giving off branches to them, partly perforate either a portion or the whole of the corpuscle, without in any instance leaving any branches of the artery in its interior; that these fine arterial branches pass through the middle of the corpuscles, then continue on their coats, and then quit them altogether; and that if an artery in the corpuscle divides into many branches—which never happens on the surface, but always in the thickness of its coats — these branches leave it again, in order to ramify minutely in the surrounding red pulpy substance of the spleen, into which part especially all the fine pencil-shaped ramifications of the arteries pass. The commencements of the veins spring from these branches; they are tolerably large, anastomose frequently with each other, and scarcely have a special coat as yet. If a little piece of the pulp of the spleen be carefully examined, it will be seen that it is as if cribriform, and constitutes as it were a network of red partitions, the diameters of which are larger than the interspaces and canals existing between them. It is these venous canals which give the cellular appearance seen in inflation of the veins of the pulp, and which, injected, form structures resembling the corpora cavernosa of the

penis. Special cells or cavities do not exist.

So far J. Müller. If we now ask ourselves the reason of these important differences between these two authors cited, one of whom affirms the continuation of the tufts in the pulp, and a connection of Malpighian corpuscles with arteries and venous interstices only; while the other denies all this, we shall find it not very difficult to give an answer. Giesker, in his description, limited himself to the appearances met with in the human subject, while J. Müller made the pig and the ox the basis of his delineation. This circumstance will at least partially explain the want of correspondence in the two descriptions; for I find that between the spleen of man and that of the animals mentioned considerable differences exist.

In *man*, at least generally, the arteries together with the veins pass deeply into the substance of the spleen, lying in the same sheath with them, and exactly following their course. According to Giesker, the two classes of vessels accompany each other even to their final ramifications; but this is not correct. In every spleen instances occur, which are easily seen, where small veins and arteries lie very close to each other; and Giesker has evidently allowed himself to regard these particular instances as the rule, and has extended it as a description to the smallest branches of vessels. But if an arterial and venous primary branch be successively followed to their minutest ramifications, it will be seen that, sooner or later, every artery and vein, without exception, separate from each other, and follow their special path. It is not at all unusual to find this even with arteries from ½ to 1 line in diameter, but it is always the case with those of from 1-10th of a line. In such an instance the artery, setting out alone, does not perforate the sheath in which it hitherto lay, but takes with it a distinct yet often inseparable covering of the same; so that from this point forwards a special and separate venous and arterial sheath exist. And in man the Malpighian corpuscles lie only on these isolated arteries; a state which Malpighi and Müller had already described in Mammalia.

As regards the other circumstances of the arteries, I have found them exactly as Müller describes them in the lower animals. After the smaller branches of the arteries are connected with the Malpighian corpuscles, they enter into the red spleen substance, and immediately upon this each small trunk spreads out in the shape of a tuft into a large number of yet finer arteries (*fig.* 526, *d.*); and these tufts or pencils of arteries, lying in great numbers close to each other, give to the terminations of the arterial trunks a very beautiful appearance, which may be best compared to the broad crown of a (*pollard*) tree. These separate tufts, dividing and diminishing in size yet more, terminate by an immediate transition into the true capillaries; which, in a more and most minute form of 3 to 5-1000ths of a line, constitute a close and beautiful network in the separate portions of the pulp, and in those parts of it which surround the Malpighian corpuscles; although they do not form a special vascular covering for the same. Many authors seem to deny the existence of capillaries in the spleen: thus Engel * has lately altogether denied them; but this is quite erroneous. They may easily be seen in the pulp of the human spleen, by the aid of the microscope, both empty and filled with blood, and exhibit themselves as in no way different from the capillaries of other organs; and the finest of them have a diameter of only 3-1000ths of a line. J. Müller is also in error when he describes the arteries as coursing through the coats of the Malpighian corpuscle, since they always pass on its exterior. Finally, Giesker is wrong in describing the arterial pencils as spreading themselves out on the Malpighian corpuscle, and here becoming continuous with the veins; even in man it is not difficult to discover that the pencils only begin beyond the corpuscles, that they lie in the pulp, and that it is here they first break up into capillaries.

Giesker at least partially agrees with this statement when he says † that the pulp consists of nothing but the minutest arteries and veins united by fibrous tissue. The sheaths of the vessels above described are just as much more delicate as are the vessels themselves, and they are finally lost as distinct coats on the capillaries; here they form delicate fibrous membranes which connect the capillaries together, and under this form they pass through the whole of the pulp.

As to the *veins*, I must first, with Giesker, express myself in the most decided manner against all the more ancient and modern anatomists who suppose and describe venous spaces (*sinus venosi*) in the human spleen. I have bestowed the greatest attention to the dilated commencements of the veins in question, and it was only my own researches that led me to renounce the opinion that these dilatations really exist; indeed I have never been able to discover anything special or extraordinary about these veins. Firstly, as to the larger veins, which are as yet accompanied by the arteries, there is nothing very remarkable about them, with the exception of their considerable size, which has been already mentioned. They all have a membrane which is continuous with that of the smaller veins, and is least separable on that side with which the artery is in contact; this membrane is only distinguishable from the sheath of the vessels by its greater delicacy, and in company with this sheath it gradually diminishes its thickness. Orifices of the smaller veins, constituting the so-called stigmata Malpighi, are present in very small numbers in the larger veins; while, on the other hand, they are somewhat more frequent in the smaller of the vessels in question. When the veins

* Zeitschrift der Gesellschaft der Aerzte in Wien, 1847.

† Loc. cit. S. 166.

leave the arteries and pursue their way alone, they vary in some respects from this description, although not so considerably as might be imagined from the delineations which have been given of them. In the first place, the character of the branchings is peculiar, since from hence onwards, and so much the more frequently the smaller the veins become, branches are given off from the veins on all sides at very nearly right angles, and the open mouths of these ramifications are seen from within as numerous round or oval orifices lying very closely to each other. In the second place, the membranes of these veins gradually become thinner and thinner, and at the same time are blended with the similarly attenuated sheaths, so that both constitute only one delicate membrane, which is nevertheless everywhere demonstrable even in the smallest vessels which can be isolated, and which everywhere exhibits itself without any interruption as a perfectly continuous membrane. Dilatations or pouchings can nowhere be seen, either in the course of the isolated veins or in their smallest branches; only it must be added, that the narrowing of their calibre occurs much more slowly than in the arteries. As to the beginnings of the veins, and their connection with the capillaries, I have not been able to detect anything more than what one sees elsewhere; namely, that by a constant simplification and attenuation of their structure, the veins finally pass into capillaries. Here also no traces of dilatations are visible, of whatever kind these dilatations might be imagined to be; and there is just as little appearance of any other peculiarity.

As regards *the brute mammalia*, many of them certainly correspond in a very considerable degree with man, in respect of the condition of these vessels; but my researches do not extend sufficiently to enable me to express myself decisively on this point. While, on the other hand, some, as the horse, ass, ox, pig, and sheep, exhibit essential differences. In the latter animal, which I have examined the most carefully, the following deviations are present. The arteries differ little from those of man, only they separate earlier from the veins to pursue their isolated course. In most other respects they behave precisely as J. Müller has described them, and as I have also spoken of them in man; only I cannot corroborate the statement of Müller, that the sheaths of the smaller arteries are equal in strength to those of the greater. The ramifications which reach the Malpighian corpuscles measure from 1 to $1\frac{1}{2}$-100ths of a line in diameter; they then course in the pulp, form very beautiful tufts, and finally capillaries, of which the smallest measure from 3 to 4-1000ths of a line. But in contrast to this, the veins exhibit very essential differences. In the first place, a special membrane and sheath are only found in the largest venous trunks, and even here they only extend a short distance around the circumference of the vessel; while more deeply in the spleen they only lie upon the side where the artery and nerve are attached to the vein. In all the smaller veins which are no longer accompanied by arteries, there is no trace of these two membranes to be seen; and not only is this the case, but the mode in which the precise limit of the venous canal is indicated is also very extraordinary. The vein appears to be formed in the first instance by the strong anastomosing trabeculæ, and soon afterwards it seems composed simply of delicate fibres and red substance deposited between them, a structure which continues even into the large venous trunks. They thus distinguish themselves at the first glance as excavations in the parenchyma of the spleen, which are devoid of walls. Nevertheless, by a more careful examination of the red limits of these veins, one may verify their smooth and shining appearances, a circumstance which is significant of the existence of a delicate membranous covering; and, in point of fact, microscopic investigation proves the existence of an epithe-

Fig. 534.

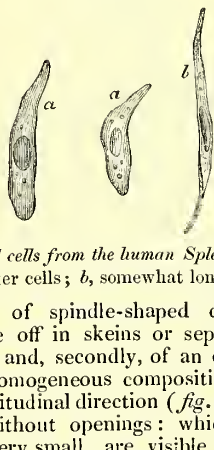
Epithelial cells from the Splenic vein of Man and other Mammalia. Magnified 350 diameters.

lium, which every where clothes this surface, and consists of fusiform or more spherical cells, of $\frac{1}{2}$ to 1-100th of a line in diameter, with roundish or elongated nuclei of 3 to 5-1000ths of a line in size (*fig.* 534.). This epithelium altogether corresponds with that which covers the part of the veins possessing a visible membrane; but in the vessels of which I am speaking, it is placed in part immediately on the trabeculæ, in part upon a delicate fibrous membrane limiting that part of the pulp which bounds the veins. In consequence of what has been said, the greater number of the splenic veins of the ox must be likened in respect of their structure to the spaces in the corpora cavernosa penis, and to the sinuses of the dura mater; since, instead of the venous membranes elsewhere present, they possess only the "*tunica intima*" in the shape of a delicate epithelium. So that one may speak of them as "*venous sinuses*," and the more correctly, if it be considered that these veins, almost devoid of walls, possess a colossal width, and are everywhere rendered quite cribriform by larger and smaller veins opening into their interior; which smaller veins may themselves be traced by their great width for a considerable distance. How these smaller veins are connected with the very distinct capillary net-

work of the pulp, I have not been able to find out; and I do not believe that either injection or inflation of the vein, or a microscopic examination, will ever give any definite conclusion hereto. For these vessels, often possessing but a few little trabeculæ for their coats, are of such a delicate texture, that they tear by the slightest mechanical force, while by the microscope they cannot be distinguished from the surrounding constituents of the pulp. Yet thus much one may see, that the veins gradually become very small,—so small, that it is quite impossible to talk of their commencing as dilated spaces. For my own part, I am convinced that a similar communication obtains between the veins and capillaries of oxen as of men; and that the only possible difference is, that the veins here possess only an epithelium, and must therefore be connected with the capillaries in a somewhat different way. I will yet further add, that in microscopic examination of the pulp of animals, skeins of epithelium are not unfrequently found, consisting of roundish cells, as it were, fused together: these can only come from the small venous trunks.

The following may be noticed concerning the microscropic structure of the splenic vessels: —The arteries everywhere possess their three usual coats. The *inner* consists, first, of an

Fig. 535.



Epithelial cells from the human Splenic artery. *a*, shorter cells; *b*, somewhat longer cells.

epithelium of spindle-shaped cells, which easily come off in skeins or separately (*fig.* 535, *a*, *b*); and, secondly, of an elastic membrane of homogeneous composition, wrinkled in the longitudinal direction (*fig.* 528, *e*.), and with or without openings: which openings although very small, are visible even in the arteries of the tufts. The middle tunic is very thick, and gives rise to the considerable thickness of the wall of the vessel; it contains very little else but unstriped muscular fibres. In the larger and largest arteries, nets of elastic fibre and elastic membrane (*gefenstirte membranen* of Henle) are also present, while they exist without exception on the vessels which pass to the Malpighian corpuscles, and on those which form the pencils or tufts. The adventitious (or cellular) coat is altogether absent from the smaller vessels in the interior of the spleen, and is here represented by the sheath; but it exists in the larger vessels, and presents white fibrous tissue and meshes of elastic fibres. The capillaries (*fig.* 536.) have a simple, structureless membrane, with nuclei lying on its

Fig. 536.

Capillary from the Spleen of the Pig. Magnified 350 *diameters.*

inner surface. The veins have been already described as they exist in brute mammalia: in man they possess — 1. An epithelium as above described; 2. A membrane of elastic longitudinal fibres; 3. Transverse unstriped muscular fibres, in a single or double layer, which are present in the trunk of the splenic vein and all its primary branches in the interior of the spleen, but are absent from the smaller and smallest veins; 4. White fibrous tissue, with elastic fibres which take a longitudinal direction. The smallest veins possess only white fibrous tissue with elastic fibres, and an epithelium.

So much has been already said above concerning the blood of the splenic vessels and of the spleen, that I will here only append some special observations made upon animals. In a dog whose spleen abounded in the dissolving blood globules, the blood of the splenic vein distinguished itself by a very great quantity of colourless blood corpuscles, almost all of which contained numerous nuclei, and often had a deceptive resemblance to pus globules. In the blood of the liver were found a great number of altogether different blood

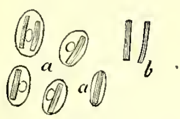
Fig. 537.

Blood corpuscles from the liver and Splenic vein of a Dog, with yellow crystals of a substance resembling Hæmatine.

globules (*fig.* 537.). These were swollen out and almost colorless, but contained from 1 to 5 thinner or thicker small rods of a dark yellow colour; part of these possessed the same length as the blood globules, part were shorter. These small rods were unchanged in water, but in acetic acid they seemed to disappear. In a second dog I found the same cells with small yellow rods in the blood of the splenic vein, while they could not be detected in any other part of the body. With them I found at the same time numerous colourless blood globules with manifold nuclei. In the fresh-water perch, the blood

of the splenic vein of many individuals contained numerous golden yellow cells with diminished blood globules. In the same blood, and in the splenic pulp, there also occurred, either sparingly or in uncommon quantity, rod-shaped crystalline corpuscles, of a yellow colour, and a length of 4 to 6-1000ths of a line : at the first glance they seemed to be lying altogether free, and they were dissolved by potash (*fig.* 538, *b*). On the application of water a membrane was upraised from these

Fig. 538.



Similar blood corpuscles from the Spleen and Splenic vein of the fresh-water Perch.

a, crystals and nuclei seen on treating colourless nucleated blood corpuscles with water; *b*, crystals apparently free.

small rods, and near them a nucleus came into view (*fig.* 538, *a*). On more accurate inquiry, it plainly appeared that these small rods lie in decolorized blood globules, and in unchanged blood globules the gradual formation of one, or even two, of these may be followed. In *Barbus fluviatilis*, the spleen pulp contains an enormous quantity of really free crystals; these are of a violet and reddish colour, and of a nail or spindle-shaped form ; and on the application of acetic acid, they are completely dissolved, leaving some colour behind. Crystals such as these also occurred sparingly in the kidneys, the liver, and the blood of the heart. In this animal, as well as in *Cyprinus brama*, the blood contained yellow granule-cells, like those which occur in the spleen and kidneys. All the rod-shaped yellow corpuscles just named (of which the first, indeed, are nothing but crystals) must in any case consist of a substance allied to the hæmatin of the blood ; and possibly they consist of the substance which Virchow has lately named hæmatoidin, with which they correspond in some respects. Their occurrence in the spleen is physiologically interesting, and so also is their formation within the blood corpuscles, while at the same time it affords a very plain indication of the relation of hæmatin to them.

7. *Lymphatics.* — The views of authors concerning the lymphatics of the spleen are very contradictory, since one class have the precedent of Haller for altogether denying their existence in the human spleen, while others have stated their existence in abundance, and have constituted the spleen, in a certain measure, a large lymphatic ganglion. This difference mainly depends hereon,—that the one class have specially examined the human spleen, while others have chiefly drawn their conclusions from that of the lower animals, considerable differences in respect of these vessels existing in different creatures. In man, the lymphatics of the spleen are, at any rate, in utterly inconsiderable quantity, being rather less numerous than in other glandular organs, as the liver and kidneys, and not at all so numerous as in the lymphatic glands. They are divisible into superficial and deep. The former course, in sparing numbers, between the two coats of the spleen, and form in this situation delicate trunks, which anastomose with each other ; but, excepting in perfectly healthy spleens, and *in the neighbourhood of the hilus*, they can scarcely be recognised. The latter lie in sparing numbers in the hilus, and in the sheaths of the vessels, where they accompany the arteries, although they cannot be traced so far as there. Both sets of these vessels pass to the gastro-splenic omentum, to enter the small lymphatic glands placed there ; and finally they collect to a trunk which opens into the thoracic duct, at about the eleventh or twelfth dorsal vertebra. All these lymphatic vessels can only be thus seen in the quite fresh and undeteriorated spleens of executed criminals or subjects killed by accidents, although they may often be recognised in particular parts of the healthy spleen after natural death, especially if the vessels be tied and the spleen soaked in water. But, on the other hand, in diseased spleens it is very rare to see even a trace of them, unless a preparation be made of a small gland in the gastro-splenic ligament, in which case small entering and emerging trunks may be recognised.

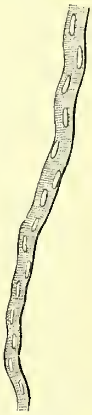
In the lower animals, or at least in many of them, the lymphatics seem to be more numerous. Moreschi distended the lymphatics of the spleen in fishes (in whom they possess no valves) from the trunk, and he says that the injected spleen appeared to consist almost solely of a network of absorbents. But in another place he freely states that the spleen consists, so to speak, of nothing but vessels. In a *Testudo mydas*, Tiedemann and Gmelin saw all the absorbents of the small intestine going to the spleen, in which, by interlacing with arteries and veins, they formed a network. From this network large branches, like the emergent vessels of the lymphatic glands, took their course towards the thoracic duct. Almost all the older writers recognised the richness of the spleen in lymphatics, which later examiners have but confirmed. But it will be well to set forth one fact which, in my opinion, is not sufficiently estimated, namely that *even here* absorbents are *only sparingly present in the interior of the spleen ;* at least I have found this to be the case in the pig, ox, sheep, &c. Here the superficial lymphatics are, as is well known, very numerous, and this fact seems to me to correspond with the circumstance that in these animals the serous and fibrous coats are only loosely connected to each other, and contain many vessels in the loose areolar tissue between them. But, on the other hand, if the vessels in the hilus be examined, only a few scattered trunks can be seen, a condition which stands in extraordinary contrast with the very numerous lymphatics of the coats. Thus, for

instance, in the hilus of a large calf I found only four trunks of lymphatics, which together possessed a diameter of only 176-1000ths of a line; while the interior of the spleen is also poor in lymphatics, for, so far as I have seen, the numerous plexuses of lymphatic trunks in the coats of the spleen have no relation with the interior of the organ, but at least the greater number of them belong solely to the subserous areolar tissue.

As to the distribution of the lymphatics in the spleen, it may easily be seen, by observations on oxen, that they only follow the course of the arteries, lying with these inside the sheaths; while the veins, which take a solitary course, and (as was before mentioned) possess no sheath, are also devoid of these companions. I have not seen the commencement of the lymphatics, yet I can state for a certainty, that they have nothing to do with the Malpighian corpuscles, since these corpuscles are completely closed, as was before mentioned. And, I will add, in support of this my view, that the small arteries which pass to the Malpighian corpuscles are no longer accompanied by lymphatic vessels; at least microscopic examination detects no trace of such vessels within their sheaths. Just as little does the pulp possess any lymphatics; for if these, like the nerves (see below), pass from the sheaths of the arteries into the pulp, they would in such a case be visible. And from what has been said, I conclude that the lymphatic vessels of the interior of the spleen belong wholly and solely to the sheaths of the arteries, and not in the least to the pulp or the Malpighian corpuscles; and thus that here they play precisely the same rather subordinate part which they do in the liver, where they pertain to the capsule of Glisson, and not to the glandular substance; or as in the kidneys, in the interior of which they only accompany the bloodvessels. Concerning the structure of the lymphatic vessels, I can only state thus much; that in the calf they possess, at least in their main trunks, three membranes:— 1. An epithelium similar to that of the arteries; 2. A circular fibrous membrane, composed of two or three layers of very distinct unstriped muscular fibres; 3. An outer membrane of white fibrous tissue. Valves occur in the deep as well as in the superficial lymphatics.

8. *Nerves.*— The nerves of the spleen arise from the splenic plexus, and accompany the splenic artery as two or three interlacing trunks, and divide in such wise at the giving off of its branches, that each artery receives one, or very frequently two nerves, which accompany it, and here and there anastomose with each other. The thickness of the primary nervous trunks varies very much in different creatures. Thus in the sheep, and especially in the ox, they are of really a colossal size, and taken all together, their diameter equals that of the empty and contracted splenic arteries; while in man and the pig they are no way remarkable in size, and are many times smaller than the arteries. These differences, which led the earlier authors to speak of the splenic nerves in similarly different expressions, were at first altogether inexplicable to me, since I could not understand why the spleen of one animal should possess so much larger nerves than another. On a more careful examination, the microscope gave a very simple and unforeseen explanation. The uncommon size of the splenic nerves of Ruminantia depends solely on this,— that the white fibrous tissue of these nerves is disproportionally developed in the shape of the so-called "fibres of Remak," while it is much less prominent in the same nerves of other animals. A comparison of the splenic nerves of the pig and calf has taught me that if we limit our inquiry to the number of primitive nerve fibres, scarce any difference exists between the two sets of nerves. But, on the other hand, the primitive nerve fibres of the pig lie very closely together, so that they cannot be numbered without considerable trouble; while as an example of their condition in the calf, I will adduce the following:— The trunks of the nerves entering the hilus were seven in number, with a diameter of ·57, ·2, ·048, ·6, ·48, ·48, ·6 (line); and they contained respectively only 28, 7, 6, 9, 13, 9, 22 primitive nerve fibres. In the lower animals, the nerves may be followed with the knife for a considerable distance into the spleen, much further than in man; and with the help of the microscope, I have very frequently followed them even on the arteries which go to the Malpighian corpuscles. I have been just as little able as Remak to find any ganglia on the arteries in the interior of the spleen. Concerning their mode of termination, I am only able to say thus much; that the nerves also pass into the pulp, and may even be easily seen on the pencils of arteries, and finally that they disappear as very small branches of not greater size than the smallest capillaries; but I am unable to decide whether they terminate by means of

Fig. 539.



A very small nerve from the Spleen of the Calf, without any visible primitive nerve fibres, and apparently consisting only of neurilemma (or fibres of Remak). Magnified 350 *diameters.*

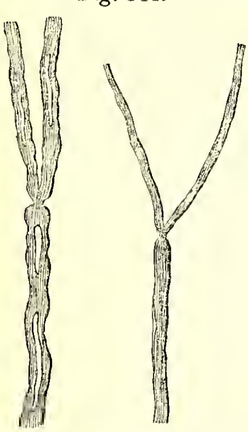
loops or with free extremities. In the calf, the thickness of these smallest nerves on arteries of a line in diameter (where it is not uncommon to find two such trunks) is 24 to 28-1000ths of a line; on the pencils of arteries 48 to 56-10,000ths; on the smallest arteries and capillaries 3 to 4-1000ths. Their structure was so far peculiar, that in the calf the finest nerves (*fig.* 539.) exhibited no trace of nerve fibres, even when treated with soda and acetic acid, but they seemed to consist wholly and solely of the fibres of Remak. Nevertheless, in branches of 12 to 28-1000ths of a line, I have often very plainly seen a single

Fig. 540.

A somewhat larger nerve, in which may be seen a single dark nerve fibre: also from the Calf. Magnified 350 *diameters.*

nerve tubule of 20 to 28-10,000ths of a line (*fig.* 540.), with dark margins, in the midst of the fibres of Remak. From these facts it may be concluded that the finest nerve tubes in the spleen of the calf are devoid of the dark borders, just as they are in the organ of smell according to Todd and Bowman; or as in the Pacinian corpuscles, the cornea, &c.; but we are scarcely able to conclude therefrom that they possess the same constitution in the adult animal. I will here permit myself to

Fig. 541.



Two primitive nerve fibres given off from the trunk of the splenic nerve of the Calf, about an inch before its entry into the Spleen. Magnified 350 *diameters.*

add an interesting microscopic observation concerning the splenic nerves of the calf. A *division* of the *primitive nerve fibres* takes place in them (*fig.* 541.), similar to that which Henle and myself found in the Pacinian corpuscles, Müller, Brücke, and R. Wagner in the muscles, and Savi and R. Wagner in the electrical organ of the torpedo. But what is *altogether new* in the minute anatomy of nerve is, that these divisions do not take place at the terminations of the primitive nerve fibres, but *in their trunks*. I detected them in the large trunks which accompany the splenic artery previously to its entering the hilus; and, indeed, in considerable numbers, so that I often counted three or four such divisions in one preparation. They always took place by the division of a primitive nerve fibre at an acute angle into two parts, and never gave rise to more fibres. These divisions often repeated themselves on the same fibre, so that in one instance three, and in another case even four, fibres were given off by the successive divisions of a single primitive fibre: this happened in the smaller branches in the interior; but, so far as I could remark, it did not occur in the smallest branches of nerves, although, from the difficulty of examining the finer nerves, I cannot say that such divisions were absolutely wanting here. The signification of these facts seems to be very important, both in an anatomical and physiological point of view, but this is not the place to give a more detailed statement. But thus much will I remark: that by means of such a distribution of the nerves, a small nerve may be rendered subservient to a larger organ; and, in addition, an harmonious activity of the whole organ may be facilitated; while, finally, in respect to sensation, it may possibly explain the want of an exact local sensibility.

In concluding this treatise on the anatomy of the spleen, I will allow myself *briefly* to propound somewhat concerning the physiological and pathological *properties* of the organ.

The spleen is developed at the end of the second or the beginning of the third month, in the fœtal mesogastrium at the fundus of the stomach. It originates from a blastema which is developed independently in this situation, and neither proceeds from the intestine, like that of the liver, nor from the pancreas, as Arnold has maintained; since, although in the ruminants it is placed on this gland, yet in the dog, according to Bischoff, it is not. It is at first a small, white, often slightly lobulated corpuscle, which gradually reddens, and soon becomes as rich in vessels and blood as it is in the adult. The elements of the fœtal spleen are originally quite uniform cells; at a later period part of these are transformed into fibres and vessels, while part become persistent as the parenchyma-cells. It is only subsequently that the Malpighian corpuscles are developed, yet I have found them, without exception, both in man and animals, at the end of the fœtal life. According to Heusinger, the proportion of the

spleen to the whole body is, in an embryo of ten weeks old, as 1 to 3000; in the eighth month it is, according to Huschke, as 1 to 720; while at birth, he states it to be as 1 to 357; in the adult as 1 to 235 to 400; and in old age as 1 to 600 to 800. From these data it will be seen, that the proportionate weight of the spleen to that of the whole body increases very rapidly in the embryo, and is almost as great at the period of birth as in the adult; from which it sufficiently follows, that the spleen is an organ, the activity of which extends from the end of the fœtal period through the whole life, and reaches its highest point in middle age.

As regards the *function* of the spleen, of the innumerable theories and hypotheses respecting it, only a very few deserve a nearer consideration; namely, only those *which place the spleen in intimate relation with the life of the blood.* In point of fact, almost all the facts which with greater or less certainty we know concerning the spleen, and, above all, the anatomical ones, point to such a relation. Hewson had already stated, that when an organ receives more blood than it requires for its own nutrition, we may conclude therefrom that that blood undergoes a change in it, or a secretory process takes place; and this expression will not apply to any organ in the body better than to the spleen, which must be considered as relatively better supplied with blood than any other organ. Therefore since all pathological, anatomical, and physiological facts prove a relation of the spleen to the blood, we may securely assume, that a change of the blood takes place in the spleen. The only difficulty is to know what change. Firstly, the blood may either suffer a change in its transition from the arteries to the veins; or, secondly, the separation of a particular lymph from the blood may take place in this organ. It is well known that the latter view was first maintained by Hewson *, who at the same time announced that the lymph generated in the spleen serves to form blood corpuscles; and since then, Tiedemann and Gmelin have specially supported the same view. But the grounds adduced for this theory seem to me to be insufficient. At one time, the great quantity of lymphatics in the spleen was brought to prove that a special lymph was developed here. But that part of the spleen on which special stress is laid, namely, the interior or parenchyma, is quite poor in lymphatic vessels; and its surface, even in the lower animals, scarce contains more of such vessels than other organs; to wit, the peritoneum covering the liver, the pleura covering the lungs, &c. Therefore the formation of a special lymph by the spleen can as little be assumed as in the case of the lungs and liver. Secondly, the red colour of the spleen-lymph, and its greater coagulability, have been adduced as proofs of a peculiarity, and of a blood-forming import. But it may be demanded, are these properties constant, and on what do they depend? As to the first question, it is certain that a red colour of the spleen-lymph is, on the whole an *exception*, as Seiler and Ficinus * formerly stated. In rabbits, cats, or dogs, I have never found such a colour, and have also always found the chyle of the thoracic duct of only different shades of white. But I will not deny that in calves and sheep a reddish spleen-lymph is often found, and I will add that this is frequently the case in the horse. But this is sometimes the case in other organs, as, for instance, in the liver and in the lacteals, where Tiedemann and Gmelin in some cases also found a reddish and very easily coagulable fluid; and it is important to observe, that the reddish colour and easy coagulability in these cases depend simply on blood which is mixed with the lymph. Thus, if the reddish spleen-lymph of a calf be examined, a quantity of fully developed blood corpuscles are found in it, which are altogether identical with those in the blood.† Now since it cannot be assumed that real coloured blood globules are formed in the lymphatic vessels of the spleen, and since, in point of fact, all trace of such a developement of blood globules is absent, it will only follow from the facts adduced, that in the cases of reddish spleen-lymph a mixture of real blood and lymph has taken place. This mixture may be the result of normal anastomoses between lymph and bloodvessels, or may owe its origin to a rupture of both these vessels. I believe the latter to be the case, and am simply of the opinion that it is not at all to be wondered at. For in Tiedemann's cases the animals were either killed by a blow on the head, or died during convulsions; and it is not surprising that during such a death-struggle an organ so richly supplied with blood as the spleen should make an abnormal path for that fluid, or that a similar thing should happen when the vena porta has been tied. It is well enough known, how easily the lymphatics of the spleen are filled by an injection into the bloodvessels. The reddish colour and easy coagulability of the spleen-lymph in particular cases therefore proves nothing at all, except that, on account of its great vascularity, blood is more easily extravasated in the spleen than elsewhere, and enters the lymphatic vessels. Thirdly and lastly, Tiedemann and Gmelin adduce the above-mentioned course of the lymphatics in the tortoise as a powerful proof of their view; but Rudolphi ‡ found exactly the contrary, since in two large sea-tortoises not a single lymphatic of the intestine passed to the spleen, but they all went directly to the thoracic duct.

In consequence of what has been said — which I might also corroborate by many other facts could I go more into detail — it is impossible to imagine the development of a special lymph in the spleen; and hence the

* Opus posthumum, sive rubrarum sanguinis particularum thymi et lienis descriptio, 1786.

* See Giesker, S. 265.

† See also Nasse, (Wagner's Handwörterbuch der Physiologie, Band ii. S. 370.)

‡ Physiologie, Band ii. Heft 2. S. 156.

theory which ascribes to the spleen a relation to the lymphatic system, and considers it as in a certain manner a large lymphatic gland, is utterly devoid of meaning. In this manner there remains as a last resource the view, that changes occur in the blood itself contained in the spleen. But what is the nature of these changes? Are blood corpuscles possibly formed in the spleen, as has been already so often supposed? Certainly not; for in the most rigorous examination of the blood in the spleen and the larger splenic vessels, just as in the spleen-lymph, no trace whatever of the formation of blood globules can be detected, much less in blood which is exactly reversed, and is exhibiting, as I might say, at every step the plainest and most lively indications of a dissolution and decomposition. Let us recall to mind the details already given of the condition of the blood globules in the spleen. Upon the facts there mentioned, in the year 1847* I founded the conjecture that the blood corpuscles *undergo solution in the spleen, and that their colouring matter is employed in preparing the colouring matter of the bile;* a conjecture which seems to me preferable to all those which have hitherto been offered concerning the function of the spleen. If the fact be made out that new blood globules are continually arising from the cells of the chyle, it is just as certain that the blood globules must also slowly disappear in order to make room for those newly arising. And if it be considered that nobody has yet seen the least trace of a solution of blood globules in any other organ, and that, on the contrary, I have found in the spleen a healthy organ, in which, in all four classes of vertebrate animals, blood corpuscles are almost constantly undergoing decomposition, even in uncommon quantities, it will, I think, be conceded to me that I have some grounds for setting forth the hypothesis here given. It is, indeed, as yet not altogether settled whether the changes of the blood seen by me are normal or abnormal; but, as was previously remarked, so long as their pathological nature is not proved with certainty, I must continue to regard them as physiological and pertaining to healthy life. But this is not saying that they occur in all creatures in the method described above. It is highly possible that blood globules undergo dissolution in the spleen without previously forming the cells containing blood corpuscles: an opinion which is corroborated by the blood globules described above as occurring in the blood of the splenic vein of the dog and fresh-water perch: these contained crystals of hæmatine or some kindred substance, and were evidently near their destruction. Indeed, it is even possible that such a direct mode of dissolution may be the rule in some animals, perhaps even in many. And although I have regarded the spleen as an organ in which the blood corpuscles undergo dissolution, yet I have not maintained therewith that it is in all animals the *only* organ in which any thing of this kind occurs: it would therefore in no way militate against my theory if it should ever turn out that in the kidneys of fishes, the vessels of which are arranged so peculiarly, a constant and physiological solution of blood globules obtained. The following circumstances also speak for my hypothesis. That in no other way can any reasonable account be given of the changes of the blood in the spleen. Furthermore, that it elucidates the relation of the spleen to the portal system of veins; since according to it, the dissolved blood corpuscles are subservient to the formation of the bile, the colouring matter of which is so nearly allied to that of the blood. Finally, that, as will be more fully stated below, the pathological facts are proportionally in unison with it.

On all these grounds I am therefore inclined to defend the hypothesis first set forth by me of a destruction of the blood globules in the spleen; and the more so, that J. Béclard has lately maintained, that the blood of the splenic vein is always poorer in blood corpuscles than that of the other veins. He has stated this in a memoir which was laid before the Académie des Sciences in Paris on the 17th January, 1848, and published in the "Archives générales de Médicine" of October to December, 1848. Since J. Béclard's results are an important support to my hypothesis, I have permitted myself to communicate here the most important of them. Béclard has analysed the blood from the lower branch of the splenic vein, and that from the jugular vein, in fourteen dogs and two horses. In most of the instances of the analysis, (1.) the water, (2.) the blood corpuscles and fibrine, and (3.) the albumen and salts, were separated from each other; and only in the horses were the blood corpuscles and fibrine obtained separately. A deficiency of the blood globules and fibrine was always present in the splenic vein, which diminution out of a 1000 parts of blood, amounted to the following quantities in the sixteen cases.

16·54	15·94	8·51
37·11	19·67	13·06
19·43	20·80	14·91
12·82	10·88	9·40
13·92	16·06	
13·60	14·78	

On an average of the sixteen cases, the deficiency amounted to 16·08 parts. As regards the albumen, on the contrary, there was a constant increase of this constituent in all the sixteen cases, in an average of 13·02 parts. Finally, in the two analyses in which the quantity of fibrine was certified, there was the extraordinary increase in its quantity in the blood of the splenic vein of 0·3 and 0·5 parts. Béclard deduces the same conclusion from these facts which I have drawn from my microscopical examinations; namely, that the blood corpuscles normally undergo dissolution in the spleen; and I regard this conclusion as neither more nor less correctly deduced than

* Loc. cit. S. 135.

mine, for it is clear that the results of his analyses may solely depend upon this fact, that in the animals he examined, the changes which I have verified in the blood globules of the spleen, were going on in an energetic manner. If these visible changes of the blood globules, — which certainly occur in a most exquisite manner in the horse and dog,—if they be normal appearances, then is the diminution in the quantity of the blood globules, which Béclard found on analysis, also a normal phenomenon ; but if not, then he only examined a blood partially deprived of its globules by stagnation and effusion. The results of chemical analysis would then only be secure, if it were at the same time shown, that there were no visible changes of the blood globules in the spleens of the animals examined. Until this takes place, Béclard's conclusion will remain, like mine, hypothetical ; although this is in no way diminishing the merit of his observations, since I hold my own hypothesis as one which I am perfectly justified in propounding in the present state of our knowledge. But even if we suppose that the blood corpuscles are destroyed in the spleen, it is nevertheless a question how this dissolution is super-induced, and at what time it comes to pass. As regards the first of these points, in my writing previously mentioned I expressed the opinion, that the spleen is a contractile organ, and may, by virtue of its contractility, be able to dilate and contract itself, — to fill itself with blood, and again to expel the blood from it. In the state of filling itself with blood, a stagnation of blood occurs in the smaller vessels, perhaps even an extravasation ; and in this stagnant blood, the blood globules undergo destruction, since they slowly dissolve themselves, either free or inclosed in cells. This view I still regard as correct. For, firstly, it is a matter of fact that the spleen does enlarge and diminish its size, and certainly under vital circumstances which are altogether normal. Very many of the older observers have accepted this fact ; as Lieutand, Haller, Stuckeley, Rush, Clarke, Hodgkin, Home, and Dobson. This is shown by an examination of the splenic region in the living human subject (Piorry). So also it is shown by vivisection of animals, in whom I have myself seen (and especially in the dog) a very distict diminution and rounding of its outer surface. Finally, Landis *, by weighing the spleen, has recognised a distinct increase and diminution of weight. He examined at different times thirty rabbits, and finds that the average weight of the organ in five observations was :

12 hours	after eating,	0·768	grammes.†
5	„	„	·588	„
8	„	„	·548	„
24	„	„	·526	„
48	„	„	·510	„
2	„	„	·444	„

Now although it may be freely conceded that an organ like the spleen is subject to so many variations in respect of size as to render thirty observations much too small a number to afford any very definite information concerning its increase or decrease of size, it must, nevertheless, be considered, that Landis has examined the proportion of the spleen to the whole body, and to many other organs, as the stomach, liver, and kidneys, and that from this means he derived a confirmation of what the estimate of its absolute weight had previously taught ; so that his observations must be regarded as a meritorious contribution to our knowledge respecting the changes of volume which the spleen experiences. We now ask, secondly, how these changes come to pass ? Béclard states that the spleen enlarges and becomes filled with blood in consequence of the splenic vein being compressed by a muscular force ; but the nature of this he has not stated, nor can I regard his view as correct. I believe myself to have propounded a better theory when I stated, that the spleen becomes turgescent in consequence of the relaxation of the muscular fibres which exist in its balks, coats, and vessel-sheaths ; or in animals from whom these are absent, through a relaxation of the muscular fibres of the vessels themselves. A constriction of the splenic vein cannot be supposed to obtain, since the muscular fibres which it contains are but very little developed, and no other compressing force is present ; while, on the contrary, we know that in all animals the splenic artery is uncommonly muscular, and that the partitions of the spleen themselves contain distinct muscular fibres. It is these muscles and no others which, according to my researches, produce the distension of the spleen ; but not through their contracting together, but by their relaxation, which brings with it a distension of the vessels with blood, and a slower circulation of this fluid. The diminution in the size of the spleen occurs simply through the contraction of the muscular parts just named. Precisely in the same manner the corpora cavernosa of the penis become filled with blood by a relaxation of the muscles situated in their fibrous partitions ; and become poorer in blood, and smaller in size, when the muscles again contract themselves. Of course, both here and in the spleen, the nerves play an important part in the process ; probably in consequence of antagonistic relations between them and other parts of the nervous system, which at present cannot be accurately indicated. Thirdly, and finally, it may be asked, whether the blood corpuscles simply dissolve because the blood of the spleen becomes stagnant at certain times, or whether special influences are necessary to this effect ? — whether the parenchyma of the spleen or the Malpighian corpuscles may not secrete a juice, a "*succus lienalis*," of which the earlier authors speak, which exerts a solvent influence on the blood corpuscles ? As a kind of vague answer to this question, I have examined the parenchyma with respect to its

* Loc. cit.

† The "gramme" is 15½ grains Troy English. (Transl.)

reaction, and have found that without exception it has an energetic *acid* reaction. This appeared to me very extraordinary, and the more so when I thought of the great quantity of blood which the organ contains; and I was already captivated by the conjecture that this acid reaction might be of great importance. But I found that litmus paper was just as much reddened by the liver and kidneys of the calf and rabbit; and, further, that the muscular substance of the heart and the muscles of the trunk have the same effect. So that this acid reaction appears to be a general phenomenon, which is probably due to the fact, that the acids lately found by Liebig in muscle (lactic and inosic acids) also occur elsewhere. At any rate since there is as yet no exact chemical analysis of the spleen, I cannot express myself concerning the import of this vigorously acid reaction of its parenchyma; although it is very conceivable, that the acid reaction does not depend on the same causes in all organs.

As regards the time at which the blood globules experience their dissolution in the spleen, nothing definite can at present be said; but my theory appears at least to presuppose, that this process especially comes to pass some time after the reception of nutriment, since I have found the spleen of the greatest size in animals at about the time of five to twelve hours after eating, the same time at which the visible changes of the blood globules were most marked. The cause of this phenomenon seems to be, that the volume of the blood is increased after each time of taking food, and especially that a great number of new cells enter from the chyle. And if an equal weight is to remain in the organism, then, on the other hand, just as many elements of the blood must be dissolved, as there have new ones entered into it; and this is exactly what happens in the spleen. Besides, I am not anxious to maintain that the spleen may not become distended, and blood globules undergo dissolution, at other times than those just mentioned; probably the conditions of the liver have also a great influence upon the events in the spleen, so that in hyperæmia of the liver, the spleen becomes also distended; and so likewise the nervous system may be interested therein. Béclard, who has also found many variations in the blood globules contained in the blood of the splenic vein, is unable to assign any definite cause for these varieties, and only remarks, that in the case of a blood rich in blood globules, the amount of these lost in the spleen was greater than in the opposite case. So that it must be left to the future to bring to light the more special relations of the dissolution of the blood globules in the spleen.

I have hitherto said nothing concerning the function of the Malpighian corpuscles of the spleen. I do not regard their function as at all a peculiar one, since (1.), in many animals, as fishes and naked amphibia, these corpuscles are absent; 2. their constituents exactly correspond with those of the parenchyma of the spleen. I believe that the parenchyma-cells and the cells of the Malpighian corpuscles play exactly the same part, although I am just as little able as my predecessors to say with certainty what this is. If they are not subservient to the formation of a special fluid which takes a part in the solution of the blood corpuscles, I should be almost inclined to ascribe to the parenchyma-cells the mechanical use of forming in the first place a soft parenchyma in which the minute vessels can extend at their pleasure; and nextly, that they, as well as the elements of the Malpighian corpuscles, are simply expressions of the fact, that the spleen, as a highly vascular organ, is everywhere permeated by a fluid which is very rich in plastic matters. At the same time, it may be imagined that all these cells elaborate the fluid in which they are soaked, and after a certain kind of assimilation, again part with it, and through the blood and lymph vessels transmit it to the general circulation. The swelling up of the Malpighian corpuscles after the use of food is quite consonant with this notion. But whether this fluid is of a peculiar nature, and of different properties from that of other organs, we can only know from future chemical researches; and then only can it be determined, whether or no we are to ascribe to it a special signification.

If the spleen be the only or even the chief organ in which blood globules undergo their dissolution, in either case the part which they enact in the organism is by no means the subordinate one which many have hitherto considered it; but one which is very *full of import*. And the results afforded by vivisections and by pathology are by no means so contradictory to this expression as they are generally maintained to be. It is true that the spleen of animals may be excised without causing their death, a fact which I have myself repeatedly witnessed; it is also certain, that men can live without spleens, or with spleens completely atrophied, or rendered functionally useless by degeneration; nay, in many cases, may live without any disturbance at all,—a circumstance which is also true of animals. But what does this prove? Nothing at all; for if the spleen fails, then indeed other organs undertake its functions, and discharge them vicariously for it. Probably in these cases the blood globules undergo dissolution in the general mass of the blood, or possibly in the liver. But if this be so, the spleen is surely not therefore devoid of import or function. With equal correctness might we say, that one kidney is superfluous, because in certain cases an hypertrophied kidney enacts the part of both; or might regard kidneys generally as devoid of import, because certain rare instances of misdevelopement are narrated, in which the skin or the thoracic glands have undertaken the excretion of the urinary constituents. If the spleen is not the only organ in which blood corpuscles undergo dissolution, it is possible that these are destroyed in some small quantity in the capillaries of all the organs of the body,

Many observers, as Lecanu and Letellier, and more recently J. Béclard, have found a diminution in the quantity of blood corpuscles in the venous blood generally, although others have denied this. If this be the case, it confirms such a supposition, and would effectually explain the results of extirpation. In any case thus much is certain, that they afford no grounds for regarding the spleen as devoid of signification. Finally, we may remark in addition, that not unfrequently extirpations of the spleen give rise to considerable disturbances, and especially of the biliary secretion; a fact which very well corresponds with my supposition that the colouring matter of the bile arises from the hæmatin set free in the spleen.

If this theory of the function of the spleen which I have set forth, which Ecker has adopted, and which J. Béclard has now confirmed, be correct, it will be able to explain the diseased conditions of the spleen and their operation on the organism. But this is at present impossible, since these conditions are much too little known to allow us to say anything even approximatively correct and secure concerning their origin and import. Therefore, instead of entering upon a discursive detail of possibilities resting upon an altogether hypothetical basis, it seems to me much more suitable, simply to indicate the points to which future observers might properly direct their special attention. It is known that the enlargements of the spleen, which constitute the most serious diseases of the organ, have a special coincidence with complaints in which either a dissolution, or some other abnormal condition of the blood is present. This is the case in typhus, typhoid cholera, pyæmia, putrid exanthemata (erysipelas, scarlatina, measles), dyscrasia of drunkards, ague, scurvy, purpura, chlorosis, acute rheumatism, acute tuberculosis, &c. May not the enlargement of the spleen possibly have a share in the production of these diseases, without being so entirely secondary as most pathologists have hitherto assumed? Is it not conceivable, that in a spleen which is enlarged and distended with blood, a destruction and dissolution of the blood globules is going on on too large a scale, so that the normal composition of the blood becomes seriously prejudiced thereby? In such a case the blood would be poorer in blood globules, but its plasma would be rich in colouring matter, and possibly at first in fibrine, as J. Béclard found it to be in his analysis. May not chlorosis or scurvy, in which a considerable diminution of the blood corpuscles has been shown to exist, possibly depend in part on the disproportionate activity of an enlarged spleen? In consequence of such a too considerable destruction of blood globules in other cases, further changes of the blood may be induced, which may then end as an overcharging of the fluid with colouring matter; to wit, with the colouring matter of the bile; or as a pyæmia or the so-called white blood. On the other hand, is it not possible, that in cases of the temporary diminution, or inflammation, or degeneration, or atrophy of the spleen, other organs may undertake its functions?—as, for instance, the liver, which, indeed, is usually hypertrophied in such cases; or the general mass of blood, a state which must again give rise to peculiar phenomena? Thus, in respect of its pathology there is much which might yet be observed, if I did not consider it more suitable to conclude with the remark, that in order to the building of a larger superstructure upon the anatomical and physiological basis here given, and in aiming at anything respecting the pathology of the organ, a deliberate, careful inquiry is above all things necessary, an inquiry in which chemical analysis, microscopical research, experiment, and pathological experience, will have to go hand in hand. For if I have perhaps been able to elucidate the spleen in many respects more correctly than my predecessors, yet this account is very far from a final termination of our knowledge, and must be regarded as nothing more than a foundation-stone for an altogether new superstructure.

Morbid Anatomy. — Variations in number and form have already been alluded to. The absence of the organ is usually or always accompanied by that of other and neighbouring viscera.

On account of the obscurity which has hitherto attached to the anatomy of the organ, its diseased conditions are little understood; and it is obvious, that until morbid conditions of the spleen are examined and classified with reference to the appearances of their several anatomical constituents, there will be little to be said under the head of morbid anatomy, besides enumerating the most prominent deviations of its bulk, colour, and consistence.

Enlargement of the spleen is, perhaps, the most common of all the outward deviations. We have already seen that, within certain and very wide limits, the size of the spleen may vary, and that these wide variations are of constant occurrence even in the healthy subject, being intimately associated with its function and that of the organ. It is, therefore, only when such enlargement becomes excessive, or is associated with an alteration of texture, or occurs in the course of some of those diseases which it is known usually to accompany, that we are justified in regarding it as essentially morbid.

The enlargement of the organ, to all outward appearance, depends mainly on the increased mass of the contained blood, and is hence sometimes called hyperæmia; and the most obvious distinction of this enlargement is into two kinds:—one in which the congestion is produced mechanically; the other, in which the determination of blood to the organ can only be accounted for on the supposition of non-mechanical causes. The former of the two classes would include the swollen spleens which occur in obstructions of the portal vein, or of the vena cava, as happens in some diseases of the liver and heart respectively.